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The Effects of Computer-Assisted Contextualized Instruction

on Mathematical Word-Problem Solving

for Students with Learning Disabilities

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The Effects of Computer-Assisted Contextualized Instruction

on Mathematical Word-Problem Solving

for Students with Learning Disabilities

by

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The Effects of Computer-Assisted Contextualized Instruction
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The purpose of this research is to examine the effects of a computer simulation program on the ability of students with LD to: a) communicate mathematically, b) estimate problem solutions, and c) solve applied story problems. Eight students with LD, ranging from 9 to 11 years of age, took part in the study. The students participated in a computer-presented interactive software program, which used contextualized problem solving to target the above skills. A multiple baseline research design was used to examine: (a) improvement, or lack thereof, of student skills in problem solving, estimation, and math communication abilities, (b) interactions among the three targeted components, (c) generalization of skills to more traditional (e. g., paper and pencil/teacher directed) formats, and (d) extended generalization of acquired skills. Implications of these findings are presented as well.

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Chapter One: Introduction

In the public schools, access to computers for all students has increased dramatically. In 1983, the ratio of students to computers was 125 to 1; this number dropped substantially in 1991 to 20 to 1 (Toch, 1991). In 1995, the Office of Technology Assessment (OTA) indicated that the average public school had one computer for every nine students (Cooley, 1996). Today in public schools the ratio is 4 to 5 students per computer designated for instructional use (Cattagni & Farris, 2001; MDR, 2002). The increase in the number of computers available to students has been accompanied by research demonstrating that computers can be effective pedagogical tools. A variety of meta-analyses examining the effect sizes of computer-based instruction in general education settings have shown positive results for student achievement (Fletcher-Flinn & Gravatt, 1995; Kulik & Kulik, 1987; Kulik, Kulik, & Bangert-Drowns, 1985; Kulik, Kulik, & Cohen, 1980) and cognitive outcomes (Liao, 1992) as well as for students with mild to moderate disabilities (Fitzgerald & Koury, 1996; Schmidt, Weinstein, Niemic, & Walberg, 1986). For example, Kulik & Kulik (1991) conducted a review of research across grade levels and found an overall positive effect size of .30. In addition, Schmidt and colleagues (1986) reviewed 22 CAI research studies conducted with students with disabilities (mentally retarded, learning disabled, hearing impaired, emotionally disturbed, and language disordered) and found CAI to be largely effective; for the 16 studies with sufficient statistical information, a median effect size of .52 was found.

While these meta-analyses of effect sizes of studies utilizing technological support for students with and without disabilities indicate that computer-based technology is an effective intervention tool, research regarding computer-assisted instruction (CAI) for students with LD is somewhat limited (Wilson, Majsterek, & Simmons, 1996), especially in the area of math problem solving. This chapter will examine: a) characteristics of math difficulties among students with LD, b) the role of CAI applications and research in addressing these problems, and c) the application of NCTM (1989) standards to math problem solving research for students with LD. Finally, the statement of the problem, the purpose of the research, and the research questions to be addressed in this study will be presented.

Nature of Math Problems Among Students with Learning Disabilities

Prevalence and Basic Skill Achievement

According to the US Department of Education (2006), approximately 2.9 million students currently receive special education services for learning disabilities in the United States, and approximately half the students identified in public schools as qualifying for special education services have an identified learning disability. While data indicates that only 2% to 6.5% of elementary school aged children are affected with a math learning disability (e.g., dyscalculia) (Kosc, 1974; NCLD, 2002), resource teachers use approximately one-third of their instructional time to teach math (Carpenter, 1985). Additionally, McLeod and Armstrong (1982) reported that of all students with LD in sixth grade and above, two out of three received special instruction in the area of math. This is not surprising as students with LD often perform below grade level peers in the area of mathematics (Englert, Culatta, & Horn, 1987; Harris, Miller, & Mercer, 1995; Montague & Applegate, 1993; Parmar, Cawley, & Frazita, 1996; Swanson & Sachse-Lee, 2001; Zentall, 1990; Zentall & Ferkis, 1993). The gap between expected and achieved level of performance widens as students with LD continue in school (Cawley, et al., 1998; Parmar and Cawley, 1995). For instance, 8 and 9 year old students with LD typically perform on a first grade level in applications and computation, and have marked difficulty with applied problems (Cawley & Miller, 1989), whereas those in sixth grade perform at approximately a third grade level in basic addition (Fleischner, Garnett, & Shepard, 1982). Students with LD are characteristically two to four grades behind their grade level peers in broad mathematics (Cawley, Fitzmaurice, Goodstein, Kahn, & Bates, 1979) and may show developmental growth rates of one year for every two years of mathematics instruction, plateauing at a fifth or sixth grade level, which is the approximate level in mathematics achievement at the time of high school graduation for most students with LD (Cawley, Baker-Kroczynski, & Urban, 1992; Cawley, Kahn, & Tedesco, 1989; Cawley, Parmar, Yan, & Miller, 1998). In addition, many students with LD achieve approximately one year of growth in mathematics, as measured by grade equivalency achievement scores, during instruction in grades 7 through 12 (Warner, Alley, Schumaker, Deschler, & Clark, 1980). Woodward and Howard (1994) determined that many middle school students with LD demonstrated systematic error patterns, indicative of a lack of understanding of math algorithms and strategies, while McLeod and Armstrong (1982) note basic operations, percentages and decimals, and mathematical language difficulties for secondary students with LD. The US Department of Education

(1999) found that in the NAEP assessment of math skills for eighth grade students, students with disabilities scored between the 9^{th} and 18^{th} percentile. Students with LD typically perform poorly on mathematics portions of minimum competency tests required for high school graduation (Algozzine, O'Shea, Crews, & Stoddard, 1987), perhaps serving as one factor for the higher than average dropout rate among students diagnosed with learning and emotional disorders (Phelps & Hanley-Maxwell, 1997; US Department of Education, 2001), which the National Longitudinal Transition Study, as cited by the NCLD (2002), found to be 35%, twice the rate of students without LD. Clearly, many students with LD achieve well below what would be expected for their age or grade level and do not perform commensurate with their typical peer achievement.

Problem Solving Applications

Challenges often present for students with LD, such as computation difficulties, attention, persistence, and reading difficulties, impact students when attempting problem solving in the area of mathematics (Parmar, 1992). Montague and Applegate (2000) found students with LD rated math word problems as significantly more difficult and had a significantly lower total word problem scores than both average and gifted students. Even students with LD who perform well on basic computation measures often have difficulty with problem solving (Cawley & Miller, 1989; Lucangelia, Coi, & Bosco, 1997; Miller & Mercer, 1997; Parmar et al., 1996). Montague and Bos (1992) conducted a study in which students were interviewed regarding their math problem solving strategies while viewing videotapes of themselves solving word problems. The students were asked questions regarding their use of various problem-solving procedures. The researchers found that the students were less adept at word problem solving than non-LD peers. Interestingly, most of the errors committed were not computational errors. Instead, the students exhibited process errors, such as applying an incorrect algorithm or failing to complete all the necessary steps for problem-solving completion. Students with LD generally perform better on skills requiring the literal use of numbers than they do on skills requiring the application of their math knowledge (Algozzine et al., 1987) and commonly exhibit difficulty when encountering multi-step problems (Bryant, Bryant, & Hammill, 2000). Students with LD often have difficulty determining which operation to use (Parmar, 1992). Blankenship and Lovitt (1976) found that when students were presented with word problems with irrelevant information, they reverted to addition even if another operation was called for. Montague and Bos (1990) assert that the trouble in applying learned computational skills to problem solving stems from a lack of general problem solving knowledge. Specifically, students with LD often have difficulty representing a problem, placing it into a meaningful schema, and developing a plan for solving the problem (Montague & Applegate, 2000; Montague & Bos, 1990; Montague, Bos, & Doucette, 1991; Zawaiza & Gerber, 1989). Strategy instruction, for example the use of representational techniques, verbalization, and metacognitive strategies, has been effective in improving student problem solving performance (Butler, Lee, & Miller, 1998; Case et al., 1992; Hutchinson, 1993b; Jitendra et al., 1998; Jitendra et al., 1999; Jitendra & Hoff, 1996; Montague, 1992; Montague & Bos, 1986; Montague et al., 1993; Montague, Morgan, & Warger, 2000; Zawaiza & Gerber, 1993). However, Bottge and Hasselbring (1993) cite research by Hasselbring, Sherwood, Bransford, Mertz, Estes, Marsh, & Van Haneghan (1991) demonstrating that even when strategy instruction improved students' ability to apply correct algorithms and processes for word problem solving, when confronted with "non-scripted" real world problems students exhibited difficulties in knowing when or in what situations those algorithms should be applied. Additionally, maintenance and generalization issues are common following word problem solving instruction. For students with LD, gains in skill acquisition regarding problem solving strategies are seldom maintained and do not commonly generalize, or transfer, to other problem solving situations (Borkowski et al., 1989; Ginsburg, 1997; Meltzer, 1994; Stone & Michaels, 1986). Problems that require multi-step applications may prove especially difficult, perhaps due to an inherent lack of number sense (Cawley & Foley, 2001; Gersten & Chard, 1999) or slow operation execution (Kirby & Becker, 1988) for many students with LD.

Mathematics reform standards provided by the National Council of Teachers of Mathematics (NCTM) place an emphasis on the ability to utilize estimation and reasonableness to apply mathematical problem solving strategies to real world math problems (NCTM, 1989). The practical application of math-related life skills is crucial for everyday functioning in postsecondary education, work, and home living settings (Algozzine et al., 1987; Bottge & Hasselbring, 1993; Jitendra, Hoff, & Beck, 1999; Montague, 1997; Patton, Cronin, Bassett, & Koppel, 1997; Parmar et al., 1996; Phelps & Hanley-Maxwell, 1997). Students with LD are aware of the importance of math problem solving skills and place importance on having them (Montague, 1997). However, application of problem solving skills is an area in which many students with LD demonstrate difficulties.

Computer Assisted Instruction

Difficulties in basic math skills and problem solving application for students with LD have sparked numerous intervention studies. CAI is one intervention tool that has been found effective in both basic skill acquisition and problem solving (Gleason et al, 1990; Halpern, 1984; Irish, 2002; Koscinski & Gast, 1993; Moore & Carnine, 1989; Robinson, DePascale, & Roberts, 1989; Shiah, Mastropieri, Scruggs, & Fulk, 1994-1995; Trifiletti, Frith, & Armstrong, 1984). CAI is defined as instruction provided to students via the computer, utilizing software or hardware applications (Wilson et al., 1996) as well as instructional interventions utilizing videodisc technology; CAI can be used to present videodisc-like simulations (Boone, Higgins, & Williams, 1997; Kitz & Thorpe, 1995; Woodward & Gersten, 1992) similar to simulation software now available to the classroom teacher for instruction in compact disc (CD) format. CAI can be used in all stages of instruction: acquisition, fluency, maintenance, and generalization (Behrmann, 1994); it is not meant to replace traditional instruction or the role of the teacher, but rather to be implemented as one component in assisting students to learn skills (Lieber & Semmel, 1985; Semmel & Lieber, 1986). In their meta-analysis of the effectiveness of CAI, Kulik et al. (1980, 1991) found that CAI was more efficient than traditional instruction, requiring 20% less instructional time. Gleason et al. (1990) echoed this finding, noting that freed teacher time allows instructors to analyze data, make instructional decisions, and teach other students. For example, in a videodisc or CD-Rom simulation program, the program provides the introduction, graphic examples, and guided practice (Gersten & Kelly, 1992). The teacher is then able to focus attention on providing students with feedback and individualized support (Woodward & Gersten, 1992; Gersten & Kelly, 1992). Additionally, CAI may create more opportunities for students to participate in learning (Anderson, 1981; Becker, 1992; Shin, Deno, Robinson, & Marston, 2000). CAI use has also been linked to increased levels of student motivation and engagement (Becker, 1992; Cosden & Abernathy, 1990; Cosden et al., 1987; Kelly, 1987; Malouf, 1988; D'Ignazio, 1994). Student motivation, ease of use, freed teacher time, greater individualization, and most importantly gains in student's math knowledge, all are factors that point to logistical benefits for computers as instructional tools.

<u>Classroom implications of CAI use</u>

A variety of math studies using CAI have been conducted to date. While a few examine problem solving applications for students with LD (e.g., Gleason, Carnine, & Boriero, 1990; Shiah et al., 1994-1995), the majority focus on drill and practice applications. The focus on basic skill applications is due to several factors, including teacher willingness to use, ease of implementation, correlation with IEP objectives and goals, and the availability of this type of software (Wilson et al., 1996). This trend reflects the status of math research and instruction in the field of LD in general, where: (a) the majority of research focuses on basic skill acquisition (Cawley & Parmar, 1992; Lessen, Dudzinski, Karsh, & Van Acker, 1989; Mastropieri, Scruggs, & Shiah, 1991; Rivera & Dix, 1999), (b) classroom instruction emphasizes basic computation skills versus higher level applications and problem solving (Cawley, Miller & School, 1987), and (c) the majority of CAI programs within special education classrooms are drill and practice software programs that target basic skills (Cosden, 1988; Cosden & Abernathy, 1990; Cosden et al., 1987; Okolo, Rieth, & Bahr, 1989).

Of concern are MacArthur and Malouf's (1991) findings that computers are often used ineffectively in special education settings. If CAI is implemented in special education settings without attention to instructional components, possible ramifications exist. First, there is the issue of incorrect student responses. Although teacher monitoring of students with mild disabilities while on the computer has a significant positive effect on performance (Semmel & Schnorr, 1987, cited in Cosden, 1988), many mainstream and resource teachers of students with mild disabilities monitor student computer use infrequently (Cosden & Abernathy, 1990; Cosden, Gerber, Semmel, Goldman, & Semmel, 1987; MacArthur, Haynes, & Malouf, 1986; Semmel & Lieber, 1986). Semmel and Lieber (1986) found that when students with mild disabilities in special education classrooms participated in drill and practice games on the computer they attended well but demonstrated high error rates that went unnoticed by the special educators. In addition, students with LD worked problems without attending to important details. The issue of incorrect responses is one reason instructional feedback is a crucial element of effective CAI (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984). Closely related to incorrect responding, a second ramification of the increased use of CAI in math is the recognition that poor instruction can exacerbate math problems for students who have LD (Carnine, 1991; Kelly, Gersten, & Carnine, 1990). Implementation problems, such as inappropriate software, classroom management issues, lack of training, and constraints on teacher time are potential issues related to the effective use of computers to facilitate instruction (Cosden, 1988; MacArthur et al., 1986; MacArthur & Malouf, 1991). If CAI is administered haphazardly (e.g., allowing students to "practice" with programs targeting inappropriate skill sets or levels), the results may actually be detrimental to the acquisition and reinforcement of math skills.

CAI research base

A series of studies have focused on identifying the important instructional components for effective utilization of CAI. These include: a) feedback (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984), b) provision for fluency in responding (Hasselbring, Goin, & Bransford, 1988; Howell, Sidorenko, & Jurica, 1987; Koscinski & Gast, 1993), c) generalization of skills gained through CAI to alternative formats (Chiang, 1986; Irish, 2002; Koscinski & Gast, 1993; Shiah, Mastropieri, Scruggs, & Fulk, 1994-1995), and d) maintenance of results over time (Howell et al., 1987; Wong, 1987). A limited number of studies investigated word problem solving utilizing the computer or interactive videodisc (e.g., Bottge & Hasselbring, 1993; Gleason et al., 1990; Moore & Carnine, 1989; Shiah et al., 1994-1995). As reflected in these studies, effective CAI word-problem solving interventions will most likely require the components found in successful non-CAI word problem-solving research. These components include, but are not limited to: a) representational strategies which allow students to develop a schema for the problem (Case, Harris, & Graham, 1992; Jitendra et al., 1999; Jitendra & Hoff, 1996; Jitendra, et al., 1999; Walker & Poteet, 1989-90; Zawaiza & Gerber, 1993), b) math communication skills, including self-verbalization or meta-cognition (Hutchinson, 1993b; Montague, 1992; Montague, Applegate & Marquard, 1993; Montague & Bos, 1986), c) solving problems within context (Bottge & Hasselbring, 1993), and d) appropriate sequencing (Miller & Mercer, 1993; Silbert, Carnine, & Stein, 1990; Wilson & Sindelar, 1991).

NCTM standards

The National Council of Teachers of Mathematics (NCTM) (1989) standards present five general mathematical goals for all students, including those with LD. These are: a) learning to value mathematics, b) developing confidence in individual mathematic abilities, c) becoming mathematical problem solvers, d) learning to communicate mathematically, and e) learning to reason mathematically. The NCTM standards have been criticized within the LD literature as elitist, insensitive to diversity, vague, without empirical support, and as ignoring specific learning issues for students with LD and other learning problems (Hofmeister, 1993a, 1993b; Hutchinson, 1993a; Mercer, Harris, & Miller, 1993; Rivera, 1993). However, the goals are important to consider in word problem solving interventions for students with LD for the following reasons: (1) Traditional math instruction for students with LD does not facilitate problem solving, reasoning and communication, which are important skills (Cawley & Parmar, 1992). Current math word problem research for students with LD ignores instruction in the recommended skills of estimation and prediction, which are crucial in learning to reason mathematically. Parmar et al. (1996) note that despite the NCTM recommendations, teachers do not commonly provide word problem solving experiences for students with mild disabilities, and thus advocate a shift in focus that would emphasize problem solving applications as recommended by NCTM to enhance student analytic skills. Other researchers advocate a similar shift (Cawley et al., 1992; Cawley & Parmar, 1992; Grobecker, 1999; Mercer, Jordan, & Miller, 1994; Mercer & Miller, 1992; Salend & Hofstetter, 1996). (2) NCTM standards are the basis on which public school mathematics curricula and materials are developed and set. Despite this, Maccini and Gagnon (2002) found that the majority of secondary special education questioned had not heard of the National Council of Teachers of Mathematics (NCTM) Standards. A primary goal in educating students with LD is to allow them to function in as inclusive of a setting as possible. Targeting skill sets that peers without disabilities are exposed to, at the students' appropriate instructional level and within the scope of their specific IEP objectives, may enhance this goal. Additionally, special education teachers within public school settings may be under pressure to incorporate the standards into instruction. As Bottge & Hasselbring (1999) note, incorporating the NCTM goals into instruction for students with disabilities can be difficult. The goals are broad, and applying them haphazardly would be "malpractice" (Hofmeister, 1993b). Empirical research that considers the goals alongside components of effective problem solving is needed. (3) The goals also reflect current issues within mathematical problem solving for students with LD. For example, the goal regarding developing confidence: students with LD often have low self-esteem regarding their ability to solve math application problems (Montague & Applegate, 1993; Montague & Applegate, 2000; Montague, 1997; Montague, Bos, & Doucette, 1991) and their self-efficacy regarding math ability can be a predictor of achievement (Pajares & Miller, 1994). In addition, the ability of many students with LD to generalize learned problem solving skills to real-world problem solving applications is limited (Borkowski, Estrada, Milstead, & Hale, 1989; Ginsburg, 1997; Meltzer, 1994; Stone & Michaels, 1986). Clearly, special educators want students to be able to reason mathematically and to apply problem-solving skills to real world math problems. Raskind & Higgins (1995) advocate the use of open-ended and learner-centered technologies, such as interactive videodiscs and simulation technologies (e.g. virtual reality) to achieve this. However, few studies attempt to instruct students in contextual problem-solving situations, even though studies that have used this method have been successful (e.g., Bottge, 1999; Bottge, Chan, Heinrichs, & Serlin, 2001; Bottge & Hasselbring, 1993). (4) Research regarding the implementation of instructional methods that incorporate NCTM guidelines is necessary. Mercer et al. (1993) note that while the standards are insufficient for complete program preparation, they can be used as guidelines for the development of programs for students with LD. Special education teachers list the lack of adequate materials as a significant barrier to trying to implement the NCTM Standards into their teaching (Collins & Gerber, 2001; Maccini & Gagnon, 2002). However, before programs are developed empirical evidence regarding what to include/exclude and how to present it are needed. Giordano (1993) encourages research to determine whether or not the methods within the standards are appropriate for students with LD. The standards advocate interactive instruction where the teacher serves as a facilitator to problem solving instruction. Rivera (1993) states that curricula for students with LD must be empirically validated; research should be conducted with components from the standards incorporated, even if it is only to determine they are inappropriate.

Statement of the Problem

The problem is threefold. First, students with LD have significant difficulties in the areas of mathematics computation and word problem solving, although far more studies have investigated strategies or interventions designed to improve computational skills. Second, the word problem solving research that has been conducted fails to address several of the NCTM (1989) recommended standards, specifically becoming mathematical problem solvers in real world applications and learning to reason and communicate mathematically, using skills such as estimation and prediction. Third and finally, CAI is a recommended intervention in the area of math instruction for students with disabilities, but has been applied to word problem solving in a limited manner, and seldom in such a way as to incorporate NCTM standards. Therefore it is important to determine whether utilizing a computer presented, teacher facilitated contextual word-problem solving intervention that incorporates components of effective CAI interventions with the word problem solving research and the NCTM standards is an effective form of instruction for students with LD.

Significance of the Problem

The implications and importance of the problem are clear. The ability to solve mathematical applications is crucial for students to function in everyday living, whether at home, in postsecondary settings, or in the workforce (Algozzine et al., 1987; Bottge & Hasselbring, 1993; Jitendra et al., 1999; Montague, 1997; Patton et al., 1997; Parmar et al., 1996; Phelps & Hanley-Maxwell, 1997). The ability to solve math-based problems is a required skill that is difficult to acquire for many students with LD (Algozzine et al., 1987; Cawley et al., 1979; Cawley et al., 1989; Cawley et al., 1992; Cawley & Miller, 1989; Jitendra et al., 1999; Parmar et al., 1996; Patton et al., 1997; Warner, et al., 1980). Teachers are charged with teaching these skills to students with LD, and may feel pressure to do so in a way that addresses NCTM standards (1989). However, concern exists that teaching in real-world context may at times be haphazard or overlook crucial skills that sequenced, direct instruction and mastery learning programs commonly found in Resource rooms often provide. This concern is reinforced by information regarding CAI that indicates applying CAI without specific purpose or instructional plan can be detrimental to student learning (Carnine, 1991; Kelly, et al., 1990). What is needed is to conduct and translate research on the effective use of CAI contextual word-problem solving instruction, incorporating NCTM (1989) goals, into information regarding how such programs can be most successfully implemented for students with LD, if it is indeed a practical application. The findings of this study will be useful to professionals in the field of LD concerned with disseminating and implementing successful math intervention strategies that promote acquisition and application of real-world word problem solving skills, and also foster generalization and maintenance of skills over time.

Purpose of the Research

The purpose of this research is to examine the effects of a computer simulation program, Fizz and Martina's Math Adventures "Blue Falls Elementary" series (Snyder, 1998), on the ability of students with LD to: a) communicate mathematically (use the language of mathematics to explain skills, processes, and concepts in oral or written format), b) estimate problem solutions, and c) solve applied story problems. The software targets multiplication facts, addition and subtraction skills, one and two-step story problems, and computational estimation on a third to fourth grade functioning level in both math skills and literacy level, encouraging students to apply problem solving to an animated, interactive adventure utilizing previously acquired basic skills. It was chosen because it incorporates several of the NCTM (1989) recommended ideals as well as intervention components deemed important in CAI and/or problem-solving research for students with LD. For example: a) students solve problems in context, utilizing simulation instead of drill and practice; b) students use written and oral mathematical communication for schema development and to explain rationales for choosing arithmetic operations and computing answers; and c) the teacher acts as a facilitator to students by guiding student learning and providing feedback. Additionally, the software targets estimation/prediction in problem solving for students with LD, an area largely ignored in empirical research.

Research Questions

What impact will instruction using the "Blue Falls Elementary" program have on:

1. The percentage of correctly solved contextually presented math simulation problems?

2. The accuracy of communicating mathematics to describe information regarding the methodologies applied to solve mathematical problems.

3. The percentage of correctly estimated solutions to presented math problems?

4. Will math problem solving generalize to written story problems, presented in a non-contextualized format?

5. Will the ability to communicate mathematical information generalize to written story problems, presented in a non-contextualized format?

6. Will the percentage of correctly solved written word problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

7. Will the percentages of communicating mathematics to describe information attained during the intervention phase of the study be maintained two weeks after the generalization phase of the study?

8. Will the percentage of correctly estimated solutions to presented math problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

Chapter Two
Literature Review

CAI has been recommended as an intervention tool in mathematics research for students with LD (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984). However, the majority of CAI applications focus on computational skills and do not adhere to NCTM (1989) standards regarding teaching students to apply mathematical operations to real world problem solving situations presented in a contextual, rather than static, format. Therefore, information is needed to determine whether CAI can be combined effectively with a computer simulation software program designed to promote mathematical problem solving to evidence gains in student problem solving abilities, estimation skills and math communication skills. This section will examine the components of effective CAI interventions in the area of math, as well as important criteria in interventions in the targeted area of word problem solving for students with LD, including: (a) common themes of the research base in computer-assisted mathematics instruction, (b) common themes of the research base in mathematical word problem solving, c) intervention implications of these themes, and (d) the relevance of the literature to the current study.

Common Themes of Computer-Assisted Mathematics Instructional Interventions

In this literature review, CAI is defined as instruction provided to students via the computer, utilizing software or hardware applications, including instructional interventions employing videodisc, video, or DVD technology due to their similarity to computer simulation software now available to the classroom teacher for instruction in CD format. CAI can be used in all stages of instruction: acquisition, fluency, maintenance, and generalization (Behrmann, 1994). No one definition for CAI exists, in fact this term for instruction is rarely defined by authors who use it, nor is this type of instruction always given the same moniker. It has also been called “microcomputer instruction” (Cosden & Abernathy, 1990; Cosden, 1988; Cosden et al., 1987), “computer-managed instruction” (Hofmeister & Thorkildsen, 1984), “computer-based instruction” (MacArthur &Malouf, 1991) and instruction utilizing “multimedia” (Boone, Higgins, & Williams, 1997; Bottge & Hasselbring, 1999; Falba & Williams, 1998) or “hypermedia” (Babbitt, 1993) (For a discussion of the terms “multimedia” and “hypermedia”, as well as related terms not listed here, see Wissick, 1996). In addition, some authors choose not to label the process of utilizing the computer for instructional interventions and simply allow the research title to make clear that computer use is a component of the intervention. The article “Computer-Delivered Feedback in Group-Based Instruction: Effects for Learning Disabled Students in Mathematics” (Robinson et al., 1989) is an example. Despite discrepancies, CAI is a commonly used term within the special education intervention literature (see, for example, Bahr & Rieth, 1991; Koscinski & Gast, 1993; Malouf, Wizer, Pilato, & Grogan, 1990; Woodward, Carnine, Gersten, Gleason, Johnson, & Collins, 1986).

Common themes appear when CAI studies are analyzed. Two of the most prevalent themes are the importance of systematic feedback within CAI software (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984) and the emphasis on generalization of learned facts to other formats and settings (Chiang, 1986; Koscinski

& Gast, 1993). A final notable theme is the use of CAI to promote maintenance of skills. These themes appear across basic skill as well as application research studies.

Feedback

Feedback is defined as the information, either corrective or evaluative, provided after a student response (Thorkildsen & Reid, 1989). Mathematical intervention research investigating the use of CAI for students with LD points to the importance of corrective feedback as an instructional component (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984). For example, Robinson et al. (1989) examined the use of computer-delivered feedback in group instructional settings for students with LD. These students received direct feedback regarding the accuracy of long division solutions. Students receiving immediate computer-delivered feedback had significantly higher accuracy levels than did students who did not receive computer-assisted feedback. While the authors hypothesized that the students in the no-feedback group would complete problems more quickly and with higher fluency rates due to lack of “interruption” (prompts) by the computer program, this was not the case. The results showed that not only did the number of problems answered correctly increase for the group receiving CAI and feedback, but problems completed increased as well.

Feedback as an instructional component is also emphasized by the findings of Koscinski and Gast (1993). They analyzed the use of computer-provided "constant time delay" as an instructional component for multiplication fact acquisition and fluency. Constant time delay involves presenting a student with a prompt, waiting a specified time period for a response (usually 3-5 seconds), and then providing the student with the correct answer. The process is then repeated until the student is able to answer correctly without teacher cue. Koscinski and Gast (1993) hypothesized that the computer could provide constant time delay as a feedback method to students with LD with effective results, thereby freeing teacher instructional time. Similar to the results of the Robinson et al. (1989) study, Koscinski and Gast (1993) found that the computer-assisted feedback method was effective both in increasing the students' accuracy levels as well as decreasing the acquisition time across fact sets. Thus both accuracy and fluency were positively affected.

Trifiletti et al. (1984) also discovered positive results from CAI for students with LD, through use of a software program that included prompting cues, correction and feedback, and continuous measurement in both basic skills and word problem solving. After five months of intervention, students in the CAI mathematical treatment condition made gains of approximately two times that of students in Resource math instruction and evidenced significantly higher scores on the Key Math test. However, Wilson et al.'s (1996) comparison of computer-assisted versus teacher-directed instruction and feedback showed that students with LD performed better in teacher-directed conditions than in CAI. This study also analyzed acquisition of multiplication facts and considered fluency to be the ability to respond in three seconds or less. In the teacher-directed intervention condition students had a higher success rate, due perhaps to increased opportunities to respond. However, the authors note that students in special education settings spend a large amount of time working independently without individualized instruction.

Therefore CAI, while not as effective in this study as teacher-directed instruction, may still be preferable over systems that fail to provide immediate feedback in any format.

CAI studies targeting word problem solving also incorporate feedback as an essential component. Shiah et al. (1994-1995) conducted a CAI study focusing on the use of strategies to solve word problems. The authors analyzed the effects of three types of CAI (strategy plus animation, strategy plus static picture, and a control of no strategy plus static picture). Ten elementary students with LD participated in each condition. In the two strategy conditions, boxes prompted the students to use each strategy step. In addition, the students in the two strategy conditions worked the problems on-screen, while the control students used paper and pencil to solve the problems. Following intervention utilizing CAI, no statistically significant differences across groups were evidenced. However, students in each CAI condition showed performance gains. Unfortunately these gains, evidenced in on-line tests, did not generalize to paper and pencil assessments. Therefore, the authors concluded that while the use of CAI to teach word problem solving to students with LD is useful in generating performance gains, the lack of transfer to paper and pencil problems requires further research.

Gleason et al. (1990) also conducted a CAI word problem solving study. While this study focused on students with a variety of mild disabilities, it is noteworthy due to the limited number of CAI word-problem solving interventions published to date. In a two-group pretest/post test design, Gleason et al. (1990) utilized a strategy-instruction tutorial to teach multiplication and division story problems to students in grades 6-8. One group received the tutorial through teacher-directed instruction, while the other group was instructed through CAI. Each tutorial incorporated immediate and corrective feedback as well as on-going assessments. Similar to the results of the Shiah et al. (1994-1995) study, each group evidenced performance gains from pre to post test conditions, with no statistically significant differences between groups. These results strengthen Shiah et al.'s (1994-1995) assertion that CAI is useful in enhancing students' word problem solving performance. In addition, by comparing results across CAI and teacher-directed instruction, Gleason et al.'s (1990) study further suggests that CAI as an effective word problem solving intervention can be equivalent to the teacher in facilitating word-problem solving gains. Moore and Carnine (1989) also found this to be the case, in their study comparing active teaching instruction with an interactive videodisc, where components of instructional delivery were similar, but presented by different mediums. Students in the videodisc instruction condition performed as well as or better than those in the active teaching condition.

A final word problem solving study investigated direct instruction tutorial software in comparison to a CAI control group, again utilizing students with a variety of mild disabilities (Woodward et al., 1986). The direct instruction students were given word problem solving strategies with corrective feedback and prompts, while the control group was taught to focus on quantities and units within the word problem. Effects between the two groups were not statistically significant, leading the authors to conclude that CAI in word problem solving may be more appropriate for guided practice situations, rather than for introducing new material to students.

CAI studies feature feedback as a common intervention component, both for basic skill acquisition as well as problem solving. This is not surprising as many math errors are due to the use of incorrect strategies and procedures, such as incorrect operations, conceptual difficulties, simple miscalculations, and inadequate knowledge (Kirby and Becker, 1988); feedback to students as they attempt to solve math problems can help to address each of these issues. Research has stressed the importance of providing specific feedback to students (Gersten, Carnine, & Woodward, 1987; Kline, Schumaker, & Deshler, 1991; Lysakowski & Walberg, 1982; Porter & Brophy, 1988; Rieth & Evertson, 1988; Rieth, Polsgrove, & Semmel, 1981; Stevens and Rosenshine, 1981; Wang, 1987). Of the CAI studies described above, some directly measure the results of feedback on student performance (Gleason et al., 1990; Koscinski & Gast, 1993; Robinson et al., 1989; Wilson et al., 1996; Woodward et al., 1986), while others incorporate feedback within an overall instructional program designed to improve student performance (Moore & Carnine, 1989; Trifiletti et al., 1984; Shiah et al., 1994-1995). Only two studies did not demonstrate positive results. Woodward et al. (1986) found no advantages to CAI with feedback as an instructional component and felt it would be more appropriate for guided practice, while Wilson et al. (1996) found that students performed better in teacher-directed conditions. Both sets of authors, however, note that CAI is still a useful intervention. The remaining six studies showed student gains, such as increases in accuracy and fluency of problem solving, at a level at least equivalent to the control group (Gleason et al, 1990; Moore & Carnine, 1989; Shiah et al., 1994-1995), if not significantly above the control group (Koscinski & Gast, 1993; Robinson et al., 1989;

Trifiletti et al., 1984). While CAI interventions are not appropriate for all students at all times, the results of these six studies suggest that when CAI is utilized in math interventions, feedback should be a built-in instructional component of the software.

Generalization

In addition to feedback, a second commonly emphasized element in computer-assisted mathematics instruction for students with LD, as well as non-CAI studies, is generalization. Generalization is the likeliness that data collected reflects a general trend, and that if data were collected in a similar but non-identical manner, the same trend would be reflected (Glass & Hopkins, 1996; Lincoln & Guba, 1989). The degree to which demonstrated skills will transfer to a similar yet different task (e.g., from computer based formats to more traditional classroom formats) is important, in CAI studies in particular. Near transfer in learning (e.g., applying skills and knowledge of math concepts from one similar math program to another on the computer) is easier to achieve than far transfer (e.g., applying skills and knowledge gained from a computer based math instructional method to a non-computer based task, such as a paper-and-pencil format) (Gick & Holyoak, 1983). Far transfer is clearly the desired outcome, so that the learner can make judgments about the math skills acquired and thus adapt and apply them to a variety of situations. If students with LD cannot demonstrate skills acquired via CAI in non-CAI settings, the value of the intervention is limited. Generalization from computer-based input to more traditional paper and pencil or verbal output formats is a critical component to intervention success. Of the studies outlined above, four specifically addressed this component, with varying results.

Chiang (1986), in his study on the use of CAI on the acquisition of multiplication facts for students with LD, compared student performance on timed multiplication drills from paper and pencil baseline to computer provided drills with immediate corrective feedback. Chiang (1986) then analyzed for generalization by having each student participate in both the computer-assisted and the paper and pencil timed assessments. While Chiang (1986) did not uncover any significant advantage to CAI, he did find that the speed of fact recall increased over time and, more importantly, that the computer-based activities generalized to the paper-and-pencil timed tests.

Similarly, Koscinski and Gast (1993) found that computer-assisted learning utilizing constant time delay also generalized to non-technological settings. Student generalization was measured by assessing: (a) math facts presented in vertical rather than horizontal format, (b) the reverse of the learned fact, and (c) verbal responses to teacher presented flash cards. Generalization did occur across these settings at varied levels.

While the above two studies showed generalization to alternative formats, Shiah et al. (1994-1995) did not find that gains in word problems solving abilities generalized to paper and pencil formats and Gleason et al. (1990) found only limited generalization to occur. The students in the Gleason et al. (1990) study were able to apply skills to a near-transfer task (such as similarly worded problems presented orally); however, when presented far-transfer items (such as story problems on an achievement test) the students were unsuccessful. For students with LD, gains in skill acquisition regarding problem-solving strategies may not generalize or be maintained (Ginsburg, 1997; Meltzer, 1994; Stone & Michaels, 1986). This is evidenced in both of the studies targeting problem solving, rather than basic fact, skills (Gleason et al., 1990; Shiah et al., 1994-1995). In designing CAI problem solving interventions for students with LD, additional components may need to be incorporated in order to promote generalization.

Maintenance

Generalization and transfer of learned skills is important, as is the maintenance of these skills. Maintenance refers to whether or not results demonstrated during an intervention will continue to be demonstrated over time. Wong (1987) stressed the importance of including maintenance conditions in intervention research in order to monitor student learning. Howell et al. (1987) conducted two CAI studies that examined acquisition and fluency of multiplication facts, as well as maintenance over time. In the first study, multiplication software, "Galaxy Math", was used with a 16- year-old student with LD. The student practiced multiplication facts with this software, "racing" to complete random multiplication facts. Numbers of problems correct and time to complete the problems were measured. The investigators found that in the initial intervention phase, errors decreased and fluency increased for the student. However, when the second intervention phase was introduced a trend reversing these results was evidenced. The second study, conducted with the same student, utilized a tutorial based-package and a teacher intervention to continue to address maintenance of multiplication facts. When the CAI tutorial program was used, the student error rate decreased to zero, but increased when the student returned to baseline. In the teacher intervention phase, the student had an average of one error out of twenty questions, with no errors in the following probe stage. Therefore, Howell et al. (1987) concluded that a combination of CAI with teacher-directed instruction was more effective in maintaining the student's acquisition and fluency of multiplication facts.

Common Themes of Word Problem Solving Interventions for Students with LD

Of the CAI intervention studies above, only four target word problem solving skills (Gleason et al., 1990: Shiah et al., 1994-1995; Trifiletti et al., 1984; Woodward et al., 1986). It is interesting to note that of these four only one demonstrated significant gains for students in the CAI condition when compared with a non-CAI group (Trifiletti et al., 1984). The remaining three studies found that while students in the CAI conditions improved in word problem solving ability, these improvements were not statistically significant when compared to a control group. In addition, Shiah et al. (1994-1995) found that gains evidenced for the CAI group did not generalize when students were assessed in a paper-and-pencil format. Each of the four studies incorporated specific feedback as a major instructional component. The results seems to suggest that in problem solving instruction for students with LD, CAI may be as effective as non-CAI instruction, but shows no significant advantages. However, in building a CAI intervention to address problem solving it may also be important to incorporate more instructional strategies related specifically to math problem solving instruction. The next section will examine general word problem solving intervention literature for students with LD to glean additional information that may apply to this study. Common themes appear when the problem solving studies that have been conducted with students who have LD are analyzed. Three of the most prevalent themes are the use of: representational techniques (Case et al., 1992; Jitendra et al., 1998; Jitendra et al., 1999; Jitendra & Hoff, 1996;

Walker & Poteet, 1989-90; Zawaiza & Gerber, 1993), math communication (e.g., metacognitive, think-aloud, and verbalization strategies) (Hutchinson, 1993b; Montague, 1992; Montague & Bos, 1986; Montague et al., 1993), and contextualized problem solving (Bottge & Hasselbring, 1993; Montague, 1992). In addition, the importance of proper sequencing and estimation will be addressed.

<u>Representation</u>

The use of representational techniques, such as diagramming, metaphors, and manipulatives, is a common intervention approach in the LD problem solving literature, applied with varying degrees of success. Representation techniques use symbolic depictions of concrete information to assist students in solving word problems; these depictions may be semi-concrete, using pictorial representations of problems or physical aids such as manipulatives, or semi-abstract with ideas shown by graphic illustrations (such as student tally marks) or verbal cues (such as analogies and metaphors) (Howell & Barnhart, 1992; Jitendra & Xin, 1997). Montague and Applegate (1993) note that demonstrated problem solving difficulties for students with LD seem to be related to an inability to represent problems and thus predict appropriate solution techniques, while Hughes and Maccini (2000) note that progressing on a representational level from concrete, to semi-concrete to abstract is an effective algebraic teaching tool for students with learning disabilities. Walker and Poteet (1989-90) applied a two-group design to compare the problem solving performance of 70 middle school students with LD who were instructed in key-word methodology (e.g., the key words “left”, “gave away”, and “lost” are subtraction cues) or diagrammatic instruction (e.g., students draw a chart demonstrating the key pieces of the problem). In the diagrammatic instruction group, students drew a representation of the word problem and then utilized this information to write number sentences to develop a problem and solve it (e.g., in the problem: Jake has 8 apples. He gives two to Manny. How many apples are left? The students would draw eight apples, and then cross out two of the apples. The problem would then be written numerically and solved by counting the number of apples remaining). Student performance on one-step word problems did not increase in either the diagrammatic or key-word group. Predictably, the instruction did not generalize to two-step problems as hypothesized.

Zawaiza and Gerber (1993) also investigated the effects of diagram instruction, as well as instruction in translating word problems into the key components contained within the problem, in a three-group study involving 38 community college students with LD. The diagram group was taught to schematically chart the components within word problem and then develop a plan to solve the problem. The translation group was taught to translate the sentences within the word problem into numerical problems. The third, attention-control, group did not receive any strategy instruction, but instead participated in group discussions regarding the word problems. Interestingly, all groups showed increases in word problem solving performance from pre to post-test conditions, but there were no marked differences between groups. In addition, all groups had more difficulty with representational aspects of the problems than the computational aspects, as evidenced by error patterns.

The difficulty with representational components may be due in part to students' lack of schema (knowledge) regarding what the problem is trying to ascertain. Jitendra and colleagues (Jitendra, Griffin, Kyle, Gardill, Bhat, & Riley, 1998; Jitendra & Hoff, 1996; Jitendra et al., 1999) have investigated schema strategy for developing word problem translation and solution processes involving change, group, and compare problem types to improve one- and two-step word problems. Instruction in this schema strategy focuses on: (a) identifying the features of the problem, (e.g., change, group, or compare), (b) checking that the necessary features for the selected problem type are present (e.g., a change problem type would have to include information indicating that the initial number presented had decreased or increased due to a change within the problem), (c) designing a strategy to solve the problem, and (d) executing the correct operations to solve the problem. Utilizing this method, Jitendra and Hoff (1996) specifically targeted schema in a direct instruction single-subject intervention with three third and fourth-grade students with LD. The intervention provided the students with steps for identifying the underlying schema of a problem, determining a solution strategy, and completing the problem. Mastery learning was used to teach each step. Not surprisingly, given the direct instruction and mastery learning components of the intervention, the results for each student were positive. Percentages of correctly solved one-step word problems increased for each of the students, and these gains were maintained for two to three weeks following the study. In a similar multiple-baseline study involving four sixth and seventh-grade students with LD, results again led to increases in word problem solving performance for all four students. These gains again were evidenced in two and four-week follow-ups. Additionally, all four students increased in their performance on two-step word problems (Jitendra et al., 1999). The final study compared the use of this schema strategy with a traditional basal instruction group for 35 second to fifth- grade students with a variety of mild disabilities, including LD. Both groups (schema instruction and basal control) improved in one-step word problem solving abilities and generalized these skills to novel one-step word problems from a different math basal than the one used in the study. However, differences between groups for posttest, maintenance and generalization favored the group instructed with the schema strategy, with this group approaching skill levels of their normally achieving peers (Jitendra et al., 1998).

For some students with LD, drawing a picture to represent the information within the word problem may enhance developing a schema. This approach was investigated by Case et al. (1992), who taught four students with LD a five-step problem solving strategy which entailed: a) reading the problem, b) circling important words, c) drawing a picture to explain the information, d) writing an equation, and e) calculating an answer. Two phases of instruction, addition and subtraction, were utilized; students practiced in each until they reached a 100% criterion level. In addition, a self-instructional strategy was taught to ensure application of the above steps, with students developing their own words to describe the method. Performance on word problems improved for all students in this study, with variable maintenance rates. Importantly, the use of the strategy generalized to other settings.

Of the six studies discussed above, five showed increases in students' performances when students were instructed using a representational technique (Case et al., 1992; Jitendra et al., 1998; Jitendra et al., 1999; Jitendra & Hoff, 1996; Zawaiza & Gerber, 1993). Two of these studies compared intervention groups with control groups (Jitendra et al., 1998; Zawaiza & Gerber, 1993). Each found that while student word problem solving performance increased, the increases were not significant when compared to the control groups. This may indicate that while representational techniques are effective instructional tools, they do not hold significant advantages over other forms of word problem solving instruction, such as basal texts (Jitendra et al., 1998), translation training (Zawaiza & Gerber, 1993), or no specific strategy instruction (Zawaiza & Gerber, 1993). It is also interesting to note that in the Zawaiza and Gerber (1993) study, all groups had difficulty with representational aspects of the word problems, which may indicate that the instructional methods were not truly effective in helping students to understand what the problems required. Jitendra and Xin (1997) state that representational techniques are only effective when relationships between the key pieces of a problem are identified for the students.

Zawaiza and Gerber (1993) also found that in the attention-control group, where students participated in discussions regarding problem-solving but received no strategy instruction, students made gains equivalent to the other strategy-instruction groups. In the Case et al. (1992) study, students drew a picture to explain what the word problems were requesting. However, they also developed a self-instruction strategy, which they had to explain in their own words. These aspects of the Case et al. (1992) and the Zawaiza and

Gerber (1993) study point to benefits found in components of math communication and echo Heller and Hungate (1995), who recommend that instructors prompt students to talk about processes in order to create a representation of the problem that is useful for the student.

Math communication

Cawley & Parmar (1992) believe that a language comprehension and information processing perspective, emphasizing meaning and understanding of math terms and operations, is an effective framework for instructing students in problem solving. They cite a paper presented by Carpenter, Fennema, Peterson, Chiang, and Loef (1988) that showed students taught with a language comprehension/information processing orientation were equal in computation skills and superior in word problem solving skills when compared to students taught with an arithmetic skills orientation. Other researchers have echoed the recommendation to teach students with disabilities to use mathematical language (Garnett, 1989; Rivera & Bryant, 1992; Salend & Hofstetter, 1996) and to develop mathematical concepts and terminology (Montague & Applegate, 1993). Rivera and Bryant (1992), in their article addressing best practices in math instruction for students with special needs, note the importance of: (a) having students explain skills and concepts, (b) teaching the language of mathematics, and (c) having students explain how math is a part of daily living (p. 76). Each of these practices could conceptually fall under the heading of math communication. Mathematical communication is defined in this paper as the ability of students to, in either verbal or written form, communicate mathematics to explain information. This might include communicating concepts such as:

a) what they believe the problem is asking, b) the chosen method for solving the problem, c) the steps taken to reach an acceptable solution, and d) an explanation of why the proposed answer is rational. Although not specifically labeled as such, many word-problem solving interventions for students with LD focus on components that can be grouped under this category. While no study in the word problem solving literature for students with LD addresses all of the math communication components listed above, several target aspects of mathematical communication. For example, in a multiple-baseline design intervention Montague and Bos (1986) taught six high school students with learning disabilities an eight-step verbalization strategy: a) reading the problem aloud, b) paraphrasing, c) visualizing, d) stating the problem, e) hypothesizing, f) estimating, g) calculating, and h) self-checking. As in the Jitendra and Hoff (1996) study, students learned these steps to mastery, and then applied them, with corrective feedback, to two-step story problems. Five of the six students exhibited increases in their two-step word problem solving ability performance levels. Additionally, these results generalized to three-step story problems for four of the students, and the results were maintained by four of the students as measured after a 3-month period. It should be noted, however, that generalization criteria was only 50%.

Montague (1992) completed a similar study, combining the verbalization strategy described above (with the first step of reading the problem aloud omitted) with a metacognitive strategy of self-instruction (say the strategy), self-questioning (ask the questions), and self-monitoring (check the answers). In this multiple baseline across subjects study, six middle school students with LD received both interventions. Half of the students received one instructional method first, followed by the remaining method. The other half received the same interventions in the reverse order. The first intervention applied, regardless of which type, did not produce improvements in students' word problem solving abilities. However, both groups showed increases in correct word problem solving after the second intervention was applied, with students receiving the seven-step verbalization strategy first performing slightly better. In addition, three of the students generalized the problem-solving skills to a different setting. Despite this success, maintenance was an issue, with only two students exhibiting maintenance of skills on the first maintenance trial, and none on the second. Reteaching after the second trial led to two students regaining a 70% criterion level. Further measurement was not conducted, so it is not known whether those students maintained this level. It may be that the multitude of steps (a combination of the seven step verbalization strategy with the three step metacognitive strategy) was difficult for the students to memorize and apply in the long-term. It is important to note the initial success of the strategies however, as well as the fact that students showed an increase in general problem solving strategy knowledge from pre to post-survey.

In another similar study by Montague et al. (1993), 72 junior high school students with LD were assigned to one of three conditions, each receiving two cycles of treatment. The conditions were cognitive instruction (COG), similar to the verbalization strategy outlined above, metacognitive instruction (MET), similar to the metacognitive strategy outlined above, and a combination of the two (COG-MET). As in the Montague (1992) study, students in the COG and MET conditions were presented the reverse intervention in the second treatment cycle. The COG-MET condition received instruction in both methods in both cycles of the intervention. All three groups showed increases in word problem solving abilities on one, two, and three-step story problems, but no significant differences between groups were found. It is important to note however, that the post-test gain placed students at a performance level that was comparable to that of their non-disabled peers, a significant result in itself.

Metacognitive strategies, such as in the studies described above, fit under the category of math communication because they encourage a student to think, or self-verbalize, about a problem and the best way to solve it. Methods such as thinking aloud encourage a student to consider various aspects of a problem, rather than to focus on one word within the problem and use that word, without considering context, to determine which operation(s) is needed. For example, in the Case et al. (1992) study described earlier, four students with LD were taught a five step representational strategy with a think-aloud process included. First the researcher modeled the steps using a think-aloud process and then the students described the steps in their own words and were encouraged to verbalize the steps as they solved the problems. All four students improved in their performance of addition and subtraction word problems, and were able to generalize the strategy to other settings.

Hutchinson (1993b) also used a think-aloud approach with twenty adolescents with LD in an algebraic word problem solving study that combined single-subject research with a two-group pre/post-test design. The experimental group received a think-aloud cognitive strategy instruction that consisted of self-questions taught through modeling, prompting, practice and feedback. Students also utilized prompt cards with the self-questions and performance graphs. Results from this group showed improvements for all students in their algebraic word problem solving skills, with maintenance for 10 students and evidence of generalization as well. The experimental group scored significantly higher on post-test measures, and think-aloud evaluations showed that students were using representations before applying operations to solve the problems.

Finally, in a study where 60 fifth and sixth-grade students with LD were divided into an experimental and control group, students in the experimental group performed better than did those in the control group in answering story problems correctly (Fleischner, Nuzum, & Marzola, 1987). The two groups each were allowed the use of calculators and prompt cards with five steps (read, re-read, think, solve, and check) listed, along with an explanation for each step. The difference between the two groups was that the control group did not receive instruction and discussion in the processes of story problem solving. While these results seem to support the concept of math communication, it is difficult to make generalizations about the study, as specific descriptions of the subjects, research method, intervention method, instruction type, and results were not given.

Each of the six studies described above required the students to apply components of math communication, either to discuss the steps required to solve a problem (e.g., metacognitive training and cognitive training), to self-verbalize, or to participate in group discussions. In each of the studies students' word problem solving abilities improved, indicating that math communication is a strong intervention component. While both

Montague and Bos (1986) and Hutchinson (1993b) demonstrated maintenance and generalization, two of the studies found maintenance of student improvements to be an issue (Montague, 1992; Montague et al., 1993), one listed variable maintenance results (Case et al., 1992), and one did not address the issue of maintenance (Fleischner et al., 1987). While math communication strategies and interventions seem effective, maintenance issues may indicate that the strategies did not internalize for students, or that the number of steps in some interventions was difficult to remember. It may also be possible that students would have had better maintenance if they had developed their own explanations for using the strategies and for remembering them as reflected by research demonstrating significant improvements in learning and recall for students with LD when self-explanations were used, combined with an active interaction with information (Scruggs, Mastropieri, & Sullivan, 1994; Scruggs, Mastropieri, Sullivan, & Hesser, 1993; Sullivan, Mastropieri, & Scruggs, 1995). Pressley (1986) notes that strategy instruction in math must extend past task-specific situations to allow children to use their "problem-solving tools" in situations that involve mathematics (e.g., authentic applications). Connecting math to useful, everyday situations encourages active learning and a greater understanding of mathematical concepts (Baroody & Hume, 1991; Mercer & Miller, 1992; Scheid, 1994).

Contextualized problem solving

While many of the studies described above encourage students to examine the context of the problem to determine which operations to use, and to estimate reasonableness, the problems presented to the students were still in standard words-intext form. Though the strategies may generalize to other paper-pencil settings or be maintained for varied lengths of time, it is questionable whether students will apply them when encountered with real-world problem solving situations that require mathematics. Goldman (1989) notes that the goal of problem solving is to develop flexibility and adaptability. Jones, Wilson, and Bhojwani (1997) note the importance of adequate instructional examples. Problems set in realistic contexts which ask students to apply prior knowledge and may have multiple solutions are seldom used in math lessons for students with disabilities; yet these types of problems are important to help students interrelate skills and learning to "develop a network of procedural knowledge" (Cawley & Parmar, 1992, p. 8). The ability to solve problems in context is critical to applying mathematical problem solving to a variety of settings and situations. It is hypothesized in this study that strategies learned in solving contextualized, meaningful problems will generalize and this generalization will be maintained, clearly necessary components for a meaningful mathematical intervention. For math to be relevant to learning and learners, it should be presented in a real world context with real-life applications, especially in the area of problem solving (Bottge, 2001; Englert, Tarrant, & Mariage, 1992; Mercer et al., 1994; Mercer & Miller, 1992).

No studies were found which attempted to present problem solving in context for students with LD, although studies have been conducted with remedial students and students with a variety of mild disabilities. Unfortunately, information regarding the LD students in particular among those students with mild disabilities is not presented. However, it is worthwhile to review three problem solving in context studies that have been conducted with students with a variety of mild disabilities, as their results point to the usefulness of teaching math problem solving through "authentic" situations. Bottge and Hasselbring (1993) conducted a simulation-type study where the authors compared two conditions: standard word problem solving instruction (WP) and problem solving in context (CP) with 36 adolescents with learning problems in a two-group design. The CP instruction utilized simulations presented via videodisc, while the WP condition used unrelated, written word problems. Both groups improved on word problem solving ability from pre to post-test, and there were no differences in groups in generalizing learned skills to a written, multi-step word problem. However, the CP group, while performing as well as the WP group on these other measures, significantly outperformed the WP group on a conceptualized problem test, as well as on a conceptualized generalization task presented three weeks after the first generalization task. The demonstrated generalization and maintenance were not dependent on remembering specific strategies to apply in specific situations. Bottge (1999) found similar results for 66 students (only three of whom were LD) in general and remedial prealgebra classes. Students in the video-presented contextualized problem group again outperformed students in the written word problem group, with results generalizing to a contextualized transfer problem (building a kite), in addition to an extended real-life transfer activity in which students used their math skills to build a skateboard ramp. These results were echoed in a similar study in which eighth grade remedial students were able to match the problem solving performance of eighth grade pre-algebra students when instructed with video-based anchored instruction on applied problems (Bottge et al., 2001).

Estimation

One component that may be important to consider in problem solving is estimation. Woodward and Howard (1994) demonstrated systematic error patterns for middle school students with LD, which indicate a lack of understanding of math algorithms and strategies. Students with LD often have difficulty determining which operation to use (Parmar, 1992) and may revert to addition if unsure which operation is necessary (Blankenship and Lovitt, 1976) Additionally, some researchers speculate that students' with LD have an impaired "number sense" or ability to apply math concepts (Cawley & Foley, 2001; Gersten & Chard, 1999). Estimation is useful for students in evaluating the reasonableness of computation and an ability to estimate could combat some of the difficulties outlined above. Three common computational estimation strategies are: (a) front end, (b) clustering, and (c) rounding (Reys, 1986). In front end estimation, the numbers holding the greatest place value (the numbers in the "front") are computed, followed by smaller place value numbers. For example, 824 + 67 + 333 + 75. The numbers in the "front" are added (e.g., 800 + 300=1100). Then the tens and ones are adjusted to form sets of 100, the initial front-end place value (e.g., 24 + 75 is about 100 and 67 + 33 is about 100, equaling 200 in total). Finally the front end and adjusted numbers are added to give an overall estimate (e.g., 1100 + 200 = 1300; actual answer is 1299). This method is most often applied to computing column addition, but can be used in other applications such as multiplication as well (e.g., 546 x 3: 500 x 3 = 1500; 40 x 3 = 120; 1500 + 120 = 1620; actual answer is 1638). Clustering is an appropriate strategy to use when a group of numbers is similar in numerical value. For example, in determining how much money the top grossing movie made over the weekend, clustering could be used. Gross earnings: Friday: 20.1M(million), Saturday: 21.2M, and Sunday: 19.3M. The numbers cluster around 20M; 20 x 3 is an estimated 60 million in weekend revenue (actual weekend revenue is 60.6M). Finally, rounding is a common strategy used in multi-digit computation. Students are commonly taught to round numbers based on specific rules. For example, in 2-digit numbers, round down when the number in the ones place is 5 or less (52 = 50) and round up when the number in the ones place is 5 or greater (55 = 60). In the problem 287 x 52, rounding can be used to develop a solution estimate (e.g., 287 = 300; 52 = 50; 300 x 50 = 15,000; actual answer is 14,924). Not only is estimation useful in checking an answer for reasonableness, it is also a practical skill to have in daily life (e.g., determining approximately how much money one has in a checking account, how much money one will need for a babysitter, how long it will take to drive to grandma's house, etc.). Trafton (1986) feels students should have an "estimation mindset", an applied ability to know when and how to estimate, as well as enough knowledge to determine if an answer approaches reasonableness. In addition, estimation has been a recommended component of math programming for students with special needs (Kameenui & Carnine, 1998; Rivera & Bryant, 1992).

Interestingly, while the ability to estimate reasonableness and predict outcomes is an integral component of real-life math problem solving, no empirical studies were found for students with LD or other mild disabilities that targeted the skill of estimation or prediction in math basic fact acquisition or word problem solving in the initial targeted literature review conducted by the author. Therefore, the Educational Resources

Information Center (ERIC) database was searched for interventions targeting this skill area to include: educational journals not previously searched, students without disabilities, and educational documents such as dissertations, grant reports, etc. The key word “math” combined with each of the following: “prediction”, “problem solving”, “reasonableness”, “estimation”, “approximation”, and “mental arithmetic” yielded a total of 359 possible articles. The abstract for each of these was reviewed. Four classroom application articles were found that presented suggestions for teaching students prediction and estimation (a World Series prediction game, for example). Educators may be concerned with teaching students these skills; however, the search of the ERIC database did not reveal any empirical intervention studies in the area of mathematics that specifically targeted the ability to estimate or predict reasonableness, for students with or without learning disabilities. The skill of estimation will be examined in the current study, as addressed by research questions three and eight.

Intervention Implications

The results of CAI research combined with word problem solving research conducted to date present several intervention implications. These include: a) the use of CAI as a feedback delivery system, b) logistical benefits of CAI, c) utilizing math communication/developing a schema, d) solving problems within context, and e) the importance of generalization and maintenance.

CAI as a feedback delivery system

The first clear intervention implication is the availability of computer-assisted instruction as a feedback delivery system. Although CAI may not always be as effective as teacher delivered instruction for students with LD in the area of mathematics (Wilson et al., 1996), it is a method of feedback that has been empirically shown to have positive results (Gleason et al., 1990; Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984). In addition, CAI with feedback allows for individualization and student feedback that may otherwise be missing in classroom instruction. While research has continually demonstrated the importance of providing specific feedback to students (Gersten et al., 1987; Kline et al., 1991; Lysakowski & Walberg, 1982; Porter & Brophy, 1988; Rieth & Evertson, 1988; Rieth et al., 1981; Stevens and Rosenshine, 1981; Wang, 1987), studies examining teacher behavior of special and regular educators report low frequencies of feedback to students with disabilities (Rieth & Evertson, 1988). For example, Rieth, Bahr, Polsgrove, Okolo, and Eckhert (1987) reported that only 2% of instructional time in resource settings consisted of delivering feedback to students. This parallels the findings of Filby and Cahen (1985) that indicate that only 4% of general education instructional time in reading and mathematics is devoted to providing feedback, and those of Haynes and Jenkins (1986) showing that general and special education students spend a majority of time in independent work rather than in teacher directed or individualized conditions. Therefore, the use of computer-assisted instructional delivery as a feedback system for students with learning disabilities may be preferable over current instructional methods that place the student in independent work situations that do not provide timely corrective feedback.

Logistical benefits

The second related implication of the research studies utilizing computers in the area of mathematics is the speed and ease of use of computers as an instructional delivery system. Uses of CAI in special education have focused primarily on drill and practice programs that emphasize basic skills (Cosden, 1988; Cosden & Abernathy, 1990; Cosden et al., 1987; Okolo, Rieth, & Bahr, 1989). This may reflect the ease of implementation of such software as not only a review element, but also as an instructional assistant for the acquisition of new facts. For example, Hasselbring et al (1988) used CAI to present math facts to students with a controlled response time. Initially students were allowed three seconds to respond to a prompt. Over the series of the investigation, the amount of response time decreased to 1.25 seconds per prompt. As the amount of time to respond decreased, percentage of fluent facts increased. CAI was effective in increasing the percentage of fluent facts for students by 73%.

Ease of use, teacher willingness to apply, and the empirical need for basic computational skills all make computer-assisted instruction a logical choice for the special education classroom (Wilson et al., 1996). However, benefits of CAI for a classroom teacher apply to non-basic skill acquisition as well. Overall, CAI may be less time consuming for the teacher, allowing for greater individualization for students within the special education caseload. For example, in their investigation of CAI as the primary mode of instruction in solving story problems, Gleason et al. (1990) concluded that when a well-designed instructional program is used, students with LD can learn to solve math story problems as well from a computer as they can from traditional teacher-directed instruction. In their meta-analysis of the effectiveness of CAI, Kulik et al. (1980, 1991) found that CAI was more efficient than traditional instruction, and required 20% less instructional time. Gleason et al. (1990) echoed this finding, noting that freed teacher time allows instructors to analyze data, make instructional decisions, and teach other students. For example, in a videodisc or CD-Rom simulation program, the program provides the introduction, graphic examples, and guided practice (Gersten & Kelly, 1992). The teacher is then able to focus attention of providing students with feedback and individualized support (Woodward & Gersten, 1992; Gersten & Kelly, 1992). In Mastering Fractions videodisc program research, students with a variety of mild disabilities, including LD, consistently demonstrated improved student performance via videodisc, versus basal, instruction (Hasselbring, Sherwood, Bransford, Fleener, Griffith, & Goin, 1987; Kelly, Carnine, Gersten, & Grossen, 1987; Kelly, et al., 1990). Additionally, CAI may create more opportunities for students to participate in learning (Anderson, 1981; Becker, 1992; Shin, Deno, Robinson, & Marston, 2000). Kelly et al. (1987) found students were more engaged when taught with a videodisc curriculum, and D'Ignazio (1994) reports that students prefer integrated learning systems because of their interactive nature. CAI use has also been linked to increased levels of student motivation and engagement (Becker, 1992; Cosden & Abernathy, 1990; Cosden et al., 1987; Kelly, 1987; Malouf, 1988; D'Ignazio, 1994). Student motivation, ease of use, freed teacher time, greater individualization, and most importantly gains in student's math knowledge, all are factors that point to logistical benefits for computers as instructional tools.

Utilizing math communication/developing a schema

The third intervention implication evident from the literature review is the necessity for the targeted intervention to utilize math communication to assist the students in developing a schema. If students are unable to decipher what the problem is and the best ways to approach it, real world problem solving becomes virtually impossible. Despite evidenced representation difficulties (Walker & Poteet, 1989-90; Zawaiza & Gerber, 1993), poorly developed problem schemas (Jitendra & Hoff, 1996), and potential estimation difficulties, studies which specifically targeted students' abilities to communicate mathematically, through verbalization, metacognitive and cognitive approaches or a combination of those approaches were successful in increasing student problem solving success (Case et al., 1992; Hutchinson, 1993b; Montague, 1992; Montague & Bos, 1986; Montague et al., 1993). Notice that even in the Zawaiza and Gerber (1993) study, in which the attention control group did not receive any form of strategy instruction but instead participated in group discussions about the presented problem, the attention-control group made similar gains to the two treatment groups. While there was no intention for this group to receive an intervention, the act of communicating mathematically about the problems, thus enhancing the students understanding of the problems and how to solve them, may have served as an intervention in itself, and could account for the lack of statistically significant differences between the intervention and control groups. These results reflect the beliefs of Ellis, Lenz, and Sabornie (1987a, 1987b), who recommend discussions regarding math, reasons for learning math skills, and potential applications of these skills to promote student learning and generalization. Wong (1994) also suggests peer interactive dialogue, along with student verbalization of the rationales used to select and use strategies, in order to promote unprompted student use of problem solving strategies to new tasks and situations. It is interesting to note that in Japan, where math achievement levels are higher overall than they are in the US, teachers spend a much larger portion of class time discussing and analyzing problems and how they are solved than they do presenting new problems or having students complete guided practice and independent work (Parmar & Cawley, 1991).

Solving problems within context

Some theorists believe our education system, in general, educates students in such as way as to promote inert knowledge (Brown, Collins, & Duguid, 1989; Tripp, 1993; Cognition and Technology Group at Vanderbilt [CTGV], 1990). Inert knowledge is knowledge that students store and can recall but cannot apply to solving complex or real-life problems (Langone, Malone, Stecker, & Greene, 1998; Whitehead, 1929). Zawaiza and Gerber (1993) discovered that students had more difficulty with representational, versus computational, components in word problem solving. Montague (1992) notes that the multitude of steps required in order to process a meta-cognitive or verbalization strategy may be difficult for students with LD to memorize and apply in the long-term, potentially affecting maintenance and generalization of acquired skills. Allowing students to solve problems in context, also called situated learning or situated cognition, may combat the problems of inert knowledge (CTGV, 1990, 1993, 1994; Griffin, 1995; Hedberg & Alexander, 1994; Lave, 1988; Young, 1993). For example, anchored instruction, contextually based instruction “experiences” provided via videodisc or CD-

Rom, has been effective in promoting independent problem solving skills for students with a variety of mild disabilities, including LD (Bottge et al., 2001; Bottge & Hasselbring, 1999; CTGV, 1993, 1994; Woodward & Gersten, 1992). For example, in the Bottge et al. (2001) study, eighth grade remedial students were able to match the problem solving performance of eighth grade pre-algebra students when instructed with video-based anchored instruction on applied problems. McLellan (1993) asserts that these multimedia tools are so powerful because they are based on stories, which provide students with problem-rich situations.

This reflects the findings of McNeil and Nelson (1991) who conducted a meta-analysis of 63 studies using multimedia that contained interactive video to present real-life problem solving situations. The authors found the overall effect size higher than that for CAI alone, and concluded the stimulation problem-solving aspect of the multimedia presentations was the reason for the increase in effect size. However, it is important to note that the reviewed studies were not limited to math instruction or to studies of students with disabilities. In the Bottge & Hasselbring (1993) study utilizing videodisc instruction for math problem-solving, the students not only showed gains in contextualized problem solving but also improved in solving written word problems, leading the authors to conclude that solving problems in a rich, complex context may lead to gains in more traditional problem-solving formats as well. In addition, the CP group did significantly better on conceptualized measures of problem solving and generalization, presented three weeks after completion of the intervention. The demonstrated generalization and maintenance were not dependent on remembering specific strategies to apply in specific situations. Pressley and colleagues have asserted that when students are allowed to generate their own questions and explanations, as happens when problems are solved in context, prior and new knowledge become interrelated, resulting in increased learning (Martin & Pressley, 1991; Pressley & Bryant, 1982). These findings regarding the importance of developing context are echoed in research demonstrating significant improvements in learning and recall for students with LD when coached to develop their own explanations for information and to actively interact with information rather than be passive receivers of it (Scruggs et al., 1994; Scruggs et al., 1993; Sullivan et al., 1995). Bottge (2001) asserts that adolescents with mild disabilities can match nondisabled students' performance on complex math problems when presented with problems that are interesting and engaging. This interaction with all aspects of a problem may also teach students with LD to distinguish between the necessary and incidental pieces of information imbedded in a problem (Hasselbring, Goin, & Wissick, 1989), which is important, as students with LD have shown difficulty solving word problems containing irrelevant information (Englert et al., 1987; Blankenship & Lovitt, 1976). Finally, teaching students to solve problems pertinent to them connects problem solving skills to functional use and encourages generalization to natural environments (Ellis et al., 1987a, 1987b) and post-school experiences (Bottge & Hasselbring, 1999).

Generalization and maintenance

For students with LD, gains in skill acquisition regarding problem solving strategies are seldom maintained and do not commonly generalize, or transfer, to other problem solving situations (Borkowski et al., 1989; Ginsburg, 1997; Meltzer, 1994; Stone & Michaels, 1986). Bottge (1999) asserts there are two aspects to problem solving: skill acquisition and generalization. Generalization is the evidence of the targeted behavior in conditions that are different from those present during the training (intervention) conditions (e.g., across subjects, settings, behaviors, people, or time) (Stokes & Baer, 1977). Clearly, if intervention gains do not generalize they are of less value to the students (Jones et al., 1997). Shiah et al. (1994-1995) utilized CAI tutorial programs to teach problem-solving to elementary students with LD. While the students showed performance gains, these gains did not generalize to paper-and-pencil assessments. The authors emphasize that transfer from CAI to paper-and-pencil format is often difficult for students with LD and point to the need for continued research that includes generalization as an investigated component. Their conclusions are supported by limited generalization in other CAI word-problem studies (e.g., Gleason et al., 1990; Woodward et al., 1986). Chiang (1986) and Koscinski and Gast (1993) assessed for generalization and found that gains from CAI did transfer to alternative formats. However, there have been variable results of computer-assisted mathematical instruction for students with LD. Bahr and Rieth (1989), in their review of computer games and drill and practice software with students with disabilities, note that some studies show computer-assisted instruction to be significantly superior, some studies show equivalence with traditional instruction, and some find teacher-directed instruction to be more effective. An important element in determining whether computer-based instruction is successful is whether or not the student is able to generalize the skills developed during the computer-assisted instruction to more traditional output formats used within the school, such as paper and pencil or verbal responses, and whether these skills can be maintained over time. This type of generalization was problematic in the two problem solving CAI studies presented in this chapter (Gleason et al., 1990; Shiah et al., 1994-1995).

However, maintenance and generalization were evident to varying degrees in many of the non-CAI problem solving studies examined in this chapter. For instance, Case et al. (1992) found skills acquired after instruction in a five-step schema development strategy that included drawing a picture generalized to other settings. Montague and Bos (1986) found that of the six students participating in their eight-step verbalization strategy intervention, four were able to generalize skills from two-step to three and four-step word problems and these gains were maintained for three months. However, the generalization criterion was only 50%. Students taught with a similar verbalization plus metacognitive strategy also were able to generalize skills, this time to a different setting; in this study however, maintenance issues existed for all students (Montague, 1992). It is theorized that the multitude of steps (10 in total) was difficult for the students to memorize and apply in the long-term (Montague, 1992). Using prompt cards to enable students to remember steps, Hutchinson (1993b) also showed generalization and maintenance for 50% of students participating a think-aloud cognitive strategy intervention. Hofmeister, Engelmann, & Carnine (1986) believe interactive videodisc (or CD-Rom) instruction, based on the characteristics of effective instruction, promotes generalizable problem-solving strategies. Bottge & Hasselbring (1993) found this to be true. In the interactive videodisc CP group, gains generalized to contextualized problem solving three weeks following the conclusion of the simulation problem solving intervention. The students also exhibited improvements in solving written word problems, leading the authors to conclude that solving problems in a rich, complex context may lead to gains in more traditional problem-solving formats as well. Bottge (1999) found similar results for 66 students (only three of whom were LD) in general and remedial prealgebra classes. Students in the video-presented contextualized problem group again outperformed students in the written word problem group, with results generalizing to a contextualized transfer problem (building a kite), in addition to an extended real-life transfer activity in which students used their math skills to build a skateboard ramp.

Relevance of the Literature to the Current Study

The CAI intervention literature focuses primarily on acquisition of basic math skills, while the word problem solving literature clearly places importance on student ability to communicate mathematically about what a problem represents, how to approach the problem and the steps taken to solve the problem. This study will incorporate important aspects from both overlapping bodies of literature. First, the mathematical intervention will incorporate corrective feedback as an instructional element. Majsterek and Wilson (1993) assert that this element is one of the instructional features associated with effective CAI, and current computer-based research in mathematics for students with LD clearly points to the importance of feedback (Koscinski & Gast, 1993; Robinson et al., 1989; Trifiletti et al., 1984). Second, math communication will be examined as a specific component during the study, as will estimation. While the studies examining aspects of "math communication" clearly show the need for its inclusion as an intervention component (Case, et al., 1992; Hutchinson, 1993b; Jitendra & Hoff, 1996; Montague, 1992; Montague & Bos, 1986; Montague et al., 1993; Zawaiza & Gerber, 1993), estimation is an unexamined skill, not validated for inclusion by the research base. Gersten and Chard (1999) and Cawley and Foley (2001) discuss student number sense, which may be lacking or incomplete for many students with LD. At the same time, NCTM (1989) recommendations point to a need to solve real world problems utilizing skills such as estimation and reasonableness. It is the author's opinion that the ability to estimate reasonableness in approaching and solving a problem, as well as in evaluating the solution, is crucial to applied problem solving and as such it will be examined in this study. Third, during the intervention problem solving will occur in context, again mirroring NCTM recommendations (1994) as well as results reported by researchers (Bottge, 2001; Bottge et al., 2001; Bottge & Hasselbring, 1999: CTGV, 1990, 1993, 1994; Griffin, 1995; Hedberg & Alexander, 1994; Lave, 1988; Woodward & Gersten, 1992; Young, 1993). Bottge and Hasselbring (1993) were successful in teaching students in the animated contextualized problem solving condition, with results generalizing to other conceptualized problems. The independent variable in this study will be computer simulation problem solving software. Finally, this research will include phases designed to assess for both generalization and an extended generalization (maintenance) of newly acquired word problem, math communication, and estimation skills. These stages are essential in measuring the effectiveness of the intervention for students with LD (Howell et al., 1987; Koscinski & Gast, 1983; Robinson et al., 1989;

Trifiletti et al., 1984; Wong, 1987). Professionals in the field of LD can interpret the results and determine whether such a use of CAI in mathematics is appropriate with their target population.

Chapter Three - Method

This study examined the effects of a computer presented, teacher facilitated contextual word-problem solving intervention on targeted math skills for students with LD.

Research Questions

What impact will instruction using the “Blue Falls Elementary” program have on:

1. The percentage of correctly solved contextually presented math simulation problems?

2. The accuracy of communicating mathematics to describe information regarding the methodologies applied to solve mathematical problems?

3. The percentage of correctly estimated solutions to presented math problems which (a) require 1- or 2-steps to solve, (b) contain 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) end with a close-ended question that can be scored as correct or incorrect?

4. Will math problem solving generalize to written story problems, presented in a non-contextualized format?

5. Will the ability to communicate mathematical information generalize to written story problems, presented in a non-contextualized format?

6. Will the percentage of correctly solved written word problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

7. Will the percentages of communicating mathematics to describe information attained during the intervention phase of the study be maintained two weeks after the generalization phase of the study?

8. Will the percentage of correctly estimated solutions to presented math problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

Method

This study addressed each of the research questions. Following is a description of the method used, including: (a) participants, (b) setting, and (c) research design.

Participants

Eight students, all aged 10, participated in the study. Each student qualifies as a student with a learning disability according to DSM IV (2000) criteria and has a significant discrepancy between ability (as determined by formal IQ measures) and achievement (as determined by both broad achievement scores as well as achievement subtest scores). A significant discrepancy is considered to be at least one standard deviation between the measured IQ score and a subtest or broad achievement scores on an accepted achievement test.

A statement from The Winston School (the setting of the study) reads as follows, “Diagnosis of a learning disability (LD) at The Winston School (TWS) is based on the discrepancy formula. Discrepancy scores of over on standard deviation (>15 points) below the full scale intelligence quotient (IQ) in the areas of basic reading, reading comprehension, mathematics calculation, mathematics reasoning, written expression, oral expression (expressive language), and/or listening comprehension (receptive language) are considered statistically significant and qualifies an individual for services and placement at TWS. We use the Diagnostic and Statistical Manual for Mental Disorders – Fourth Edition (DSM-IV) for diagnostic criteria and formal diagnosis terminology. We also recognize the Texas State Board of Education's areas of Learning Disabilities."

The participating students were enrolled in the fourth grade at the time the research was conducted. Descriptor information on the subjects (see Table 1, "Student Demographic and Diagnostic Data") includes gender, primary language, zip code, age, race, handedness, retention, ADHD diagnosis and whether the student was on medication at the time of the study, measured IQ, measured non-verbal IQ (where applicable), and measured achievement in the areas of broad reading, broad math, calculation, math fluency, and applied problems. Students with a primary diagnosis of emotional disturbance or behavioral disorder were not considered as participants. Students with a sole diagnosis of ADHD were not considered as participants. (For additional information regarding participant selection criteria, see the Sampling Method section below).

Insert Table 1 about here

<u>Setting</u>

The setting is The Winston School, a private co-educational college preparatory school for students of average to superior intelligence with a verifiable diagnosis of a learning disability and/or ADHD. The academy is located in Dallas, Texas. Each elementary classroom has approximately 8 to 12 students assigned based on age and skill level (determined by results of individualized testing as well as teacher observations), instructed by certified teachers only, with at least one computer per classroom. The school educates children in grades 1-12, with a total student body of approximately 230 students. Tuition and fees per year range from $14,552 to $18,787 depending on grade level. Winston offers partial financial aid to students with demonstrated financial and academic need, awarding approximately $400,000 in assistance grants in 2004. 95% of The Winston School's senior class graduates continue their education at the college level. The Winston School is accredited by the Independent Schools Association of the Southwest (ISAS) and is a member of the national Association of Independent Schools (NAIS).

Research Design

Barlow & Hersen (1984) note several pertinent limitations to traditional, experimental group research. One is the practical problem of finding large pools of persons to randomly assign to groups, which can be a particular problem when a study focuses on a group representing a small portion of the general population, such as students with LD. A second limitation relates to examining results for an entire group. This averaging of responses ignores intersubject variability in regards to the treatment. Finally, there is an ethical limitation to experimental group research: it may be objectionable to withhold treatment from groups of students who could benefit from the applied intervention. Due to these limitations, and due to reliability and validity concerns with other approaches such as the one-shot case study and the one group pretest-post test design (Campbell & Stanley, 1966), this study will utilize time-series research, employing a single-subject, multiple baseline across groups design.

As Tawney and Gast (1984) explain, single subject research allows the researcher to examine each participant's behaviors under a pre-intervention condition (baseline) and an intervention condition. In the case of the current research, the nature of the software program requires that subjects experience the intervention condition in small groups, thus a multiple baseline across groups design is used. In this design, as in all single-subject research, each student serves as his or her own control. This allows the behavior of a single participant to be studied, and allows for the targeting of specific behaviors (Richards, Taylor, Ramasamy, & Richards, 1999). Data is collected repeatedly for each participant across two or more conditions, such as baseline, intervention, maintenance, and generalization. Data trends, levels, and variability are analyzed across these conditions for each student, allowing the researcher to draw causal inferences regarding the relationship between independent (intervention) and dependent (behavioral) variables. Replication of results across participants and/or groups of participants strengthens the reliability of such inferences. The design is useful for evaluating a single intervention (e.g., use of the software program) with a small number of participants.

Single subject research is well accepted, with widespread use since the 1960s (Wolery & Dunlap, 2001). For example, Swanson (1993) found that 67% of special education journal and 68% of non-special education journal research articles were “quasi-experimental”, and placed single-subject research designs within that heading. A multiple baseline design applied across sets of subjects (groups) has the "methodological rigor" of other single-subject applications (Murphy & Bryan, 1980, p. 333) and is the recommended method for evaluating group interventions within educational settings (Murphy & Bryan, 1980). The multiple baseline across groups method allows for application of the intervention in a setting where traditional group designs would be impractical due to small numbers of students as well as ethical considerations regarding withholding an intervention from students who could conceivably benefit. Additionally, data can be collected on several behaviors (dependent variables) during one time period, and a researcher can examine any interaction effects, should those be evidenced. An additional benefit of the method is that multiple baseline designs and results are easier for the practitioner to translate from research to practice within educational settings (Guralnick, 1978; Murphy & Bryan, 1980). Additionally, by applying multiple baselines across subjects and/or groups, the intervention is replicated, increasing reliability (Kratochwill, 1978). In the current study, experimental control is demonstrated by positive changes in mathematical communication scores, percentage of correctly estimated solutions, and percentage of word problems solved correctly upon implementation of the intervention. Confidence in the experimental control improves when the change in behavior replicates across subjects, and across groups, in the study (Tawney & Gast, 1984).

Two groups of four students each were developed from the pool of referred students (for referral and selection criteria, see the Sampling Method section below). Baseline data was gathered until four students attained a steady state (Sidman, 1960). The first four students to attain a steady state comprised Group 1 in the intervention. Once baseline data points were stable for the remaining four students (Group 2), Group 2 began the intervention. The intervention was replicated twice, allowing the researcher to examine individual and group aggregate responses to the intervention, while increasing confidence in the reliability of the results.

Dependent Variables

The dependent variables include: (a) accuracy rates for contextually presented word problems (Research Questions 1, 4, and 6), (b) estimation ability (Research Questions 3 and 8), (c) mathematical communication ability (Research Questions 2, 5, and 7), (d) generalization (Research Questions 4 and 5) and (e) extended generalization (e.g., maintenance of mastered or improved skills) (Research Questions 6, 7, and 8).

Word problem solving accuracy. Word problem solving accuracy is defined as the percentage of word problems a student is able to answer correctly on a worksheet containing three problems which meet the following criteria: (a) require 1- or 2-steps to solve, (b) contain 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) not previously presented to the students by the researcher or classroom teacher. Two sample problems from Episode 2, to be discussed by the student after viewing an animated vignette, include:

1. *If Mr. Tweetig were also allergic to cheese, how many allergies would he have?*

Mr. Tweetig is Fizz and Martina's teacher. He is allergic to a dozen items, which the students learn as Fizz is narrating about his class. As they listen, the students are taking prompted notes on a “Video Notes” worksheet. The prompt for this fact says, “A dozen is the number of…” with a blank following. Students are allowed to refer back to the notes they have taken during the animated vignette to solve the problem.

2. *If Fizz’s experiment required 20 batteries, how many more batteries would Fizz need?*

As the animated vignette and Mr. Tweetig’s ‘lesson’ continues, Fizz begins to daydream about conducting an experiment with a frog, where he would attach three batteries to each leg of the frog to get it to jump. Students are asked to solve the above question, show their work, and then write a sentence describing how they arrived at the answer (e.g., “I added the number of batteries”, Student 5). This question is followed by:

3. *Write, in a complete sentence (or two), why your answer to question 1 is important for Fizz. Use the number 14 in your answer.*

Again, students were provided the information necessary to answer this question in the animated vignette, where it was revealed that Fizz had 14 batteries in his desk at home.

Below is a sample homework problem from the same episode:

Mr. Tweetig asked Fizz to get some magic markers from Ms. Currymore, the art teacher, for a project he wanted to do with Fizz’s class. There are 25 students in the class and every student needs to have one marker. Ms. Currymore gave Fizz 3 packs of markers with 8 markers in each pack.

Will there be enough markers for every student in Fizz's class? (Show work and answer in a complete sentence.)

Students were given all necessary information to solve these problems within the animated vignette. They were able to review the vignette for additional information as needed, and also were encouraged to take notes. Percentages of word problems solved correctly, with no partial credit given, were recorded for each student. The word problems focus on the following skill areas: (a) addition and subtraction with 2- and 3-digit numbers, and (b) multiplication with 1-digit numbers. This variable was assessed through all phases of the study.

Estimation ability. Estimation ability is defined as the percentage of word problems for which a student is able to correctly estimate a solution. A sample estimation problem, given after watching a simulation about Martina's after-school jobs from Episode 1, is:

Allowance: $1.75

Babysit: $1 or more

Walk dog: $2.50

Tutor: $1.15

Does Martina earn $5 or more every week?

During intervention, estimation ability was assessed using "The Estimation Game", which requires students to develop a strategy to estimate good answers to three problems (such as the one listed above) for each of the four vignettes. This game is included with the software program. During baseline, generalization and maintenance phases, estimation was measured through answers to written worksheet estimation problems (3 per worksheet) of the same type shown above. To generate these worksheets, the researcher developed a series of 102 similar problems. The problems: (a) require 1- or 2-steps to solve, (b) contain 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) end with a close-ended question that can be scored as correct or incorrect. An independent evaluator, who is a classroom instructor at The Winston School, reviewed the problems for the above criteria and compared them with those provided in the software program to ensure similarity. Any problems deemed dissimilar or not meeting the above criteria were replaced using the same method as above. Percentages of estimation problems solved correctly, with no partial credit given, were recorded for each student. The estimation problems concentrate on computational estimation strategies (front-end, rounding, clustering, and compatible numbers). Estimation ability is assessed during the baseline, intervention, and maintenance phases of the study. At the conclusion of the study, item difficulty equivalence and mean difficulty were measured. This information is listed in Table 2, and a more in-depth discussion regarding estimation performance and problem difficulty can be found in Chapter 5.

Insert Table 2 about here

<u>Math communication skills</u>. Mathematical communication is the ability to communicate mathematics to explain information. It can be demonstrated orally or in

writing. In this study, math communication skills were assessed through students' oral descriptions of how they solved problems. Descriptions focus on: (a) addition and subtraction with 2- and 3-digit numbers, and (b) multiplication with 1-digit numbers. A software provided scoring rubric, found in Table 3, was used to provide a numerical math communication score each time this variable is measured. This variable was measured during all phases of the study.

While the math communication component measured in this study required subjective evaluation, the use of a scoring rubric presents a common standard of performance for instructional groups, which can enhance objective evaluation (Luft, 1998, cited in Prestidge & Glaser, 2000; Prestidge & Glaser, 2000). To enhance the reliability of the findings regarding math communication an inter-rater reliability between the researcher and a classroom teacher was established for the scoring rubric. See more regarding this in Chapter 4.

Insert Table 3 about here

Independent Variable

The independent variable is the computer presented contextualized problem solving software "Blue Falls Elementary", a segment of Fizz & Martina's Math Adventures, published by Tom Snyder Productions (1998). The interactive group simulation software Fizz & Martina's Math Adventures consists of five series. The series used in this study, "Blue Falls Elementary", targets 1-digit multiplication facts, 2- and 3-

digit addition and subtraction, 1- and 2-step story problems, and computational estimation on a third to fourth grade functioning level in both math skills and literacy level. The software presents students with cartoon episodes in which dramatic events result in a math dilemma. Students then apply problem solving to an animated, interactive format using previously mastered computation skills. This software incorporates several of the NCTM (1989) recommended ideals as well as crucial intervention components presented in chapters one and two of this study: a) students solve problems in context, utilizing simulation instead of drill and practice; b) students use written and oral mathematical communication for schema development and to explain rationales for choosing arithmetic operations and computing answers; c) students predict answers and consequences and estimate the reasonableness of these predictions; and d) the teacher acts as a facilitator to students by guiding student learning and providing feedback. This software is not designed to teach basic skills, but rather to encourage students to apply problem solving to an animated, interactive adventure utilizing basic skills that have already been mastered. It should be noted that this Independent Variable is presented by the researcher versus the classroom teacher.

Software description. The “Blue Falls Elementary” title consists of an introductory activity and four simulation episodes that address the targeted areas of estimation, applied problem solving, and mathematical communication. There are also follow-up activities and homework assignments to accompany each of the episodes. The introductory activity consists of a video segment (shown on the computer via the CD-Rom). In this segment, the animated characters Fizz, Martina, and their teacher explain and model how students will work together to solve problems during the series. The video has breaks in which the students can practice the process in small groups. Students learn: a) how to record facts presented in the story, b) to explain how they arrived at an answer using oral and written communication without numerals, and c) how answers are decided upon and shared. Each of the four remaining episodes consists of two story problems presented through simulation. Students watch the videos while taking notes (filling in blanks of a pre-prepared worksheet). Students then prepare to answer three team questions within a specified time limit. Question one states the problem and calls for a numerical answer. Question 2 requires students to explain without using numbers how they arrived at a solution to Question 1. Question 3 asks students to predict the consequences of their answer in the context of the video. The teacher monitors and assists during this process, but does not provide students with the correct answer. The teacher then utilizes the computer to randomly select "teams" to answer each question in a "Team Quiz". However, as only four students participated in the Intervention phase at a time, each student was assigned a color. When the computer selected a "team" color, that individual student was called upon. To be counted as correct, the student had to be able to explain his/her answers without looking at their written work. Incorrect answers were used as re-teach opportunities. (Note that this definition of correct and incorrect applies only to the intervention method and does not impact assessment of dependent variables in any way. Scoring of assessments for data analysis remains the same as is described in the method sections above.) Once this process was completed, students proceeded with the second problem within the episode, following the same steps again. Finally there is a short final video segment concluding the episode.

After each episode, follow-up activities are provided: a) “Trivial Computes”, which provide additional computational practice utilizing facts and numbers from the video; b) “The Estimation Game”, which requires students to develop a strategy to estimate good answers to three problems; and c) “Homework”, which consists of a practice problem and a write-your-own-story-problem. These activities are optional but two, “The Estimation Game” and “Homework”, are applied in this study. Each of the episodes with follow-up activities was estimated to take approximately one to two 45-minute class periods to complete. However, this time estimate was not always accurate, as is documented in the Results and Discussion chapters of this study.

Sampling Method

Students, aged 9-11 in grades 3-5, were eligible to participate in the study based on their identification as a student with a learning disability and on teacher referrals. Following an initial meeting with key staff members at the Winston school (Head of School, Head of Upper School, Head of Testing/Admissions, Counselor, and Diagnostician), a teacher meeting was set. Teachers were given an overview of the research and software, and given a description of the type of student appropriate for the study, as well as a written referral form (see Table 4) listing specific student participation criteria: (a) ages 9-11, (b) grade level 3, 4 or 5, (c) literacy level of 3rd grade or above, (d) math skill level of 3rd grade or above: 80% proficiency with 2- and 3-digit addition and subtraction with regrouping; 90% proficiency with 1-digit multiplication facts 0-9, (e) word problem solving and/or computational estimation difficulty, and (f) documented learning disability. Teacher discretion was used in deciding which students to refer (as long as the students meet the above criteria), with the researcher available to answer any questions. Teachers were asked to refer students who demonstrate proficiency in basic 2- and 3-digit addition and subtraction (80% proficiency) and simple (1-digit) multiplication facts (90% proficiency), but had difficulty applying these skills to problem solving, including estimation (below 70% proficiency). Proficiency levels were teacher determined and based on items such as student classroom work, homework, reading and mathematical assessments, as well as standardized assessments. Although referred students needed to demonstrate comprehension, a reading level at the third grade level was not required as a read-aloud modification was applied groups, spelling was not counted against students, and writing assistance was available as well, including dictation as necessary. Students with a primary diagnosis of emotional disturbance or behavioral disorder were not considered as participants. Based on this information, ten students were referred for participation in the study. Students one through seven were referred based on difficulties in both word problem solving and estimation, while student eight was referred in the area of word problem solving only. Parents of the referred students were invited to attend an informational meeting in which the researcher provided an overview of the research, demonstrated a sample of the software, and answered parental questions. Parental consent to participate in the study was given for eight students. Students one through seven were referred based on difficulties in both word problem solving and estimation, while student eight was referred in the area of word problem solving only.

Each of these students consented to participate in the study and compose Groups 1 and 2. All of these students were enrolled in fourth grade at the Winston School. All of the students received weekly computer lab instruction. In addition, there were three computers available to share between two classroom teachers. The in-class computers were not used as a mode of instruction in mathematics, but were periodically utilized for skill practice by the students. For demographic and diagnostic data on the students, refer to Table 1 above. Student assignment to particular groups was based upon attaining a steady state in baseline. Students were assigned to groups according to the order in which they achieved a steady state. For example, the first four students with stable baseline data comprised Group 1.

Insert Table 4 about here

<u>Conditions</u>

<u>Baseline</u>. In order to counteract instability, a possible threat to internal validity, and to rule out the possibility that results reflected an already occurring trend, baseline data on the students was collected either until stable for all three dependent variables for each student (Kratochwill, 1978) or until a trend in the opposite direction of the desired results (e.g. a downward trend) occurs. In order to establish trend (or lack thereof) during baseline a minimum of three plotted data points is required. Successively upward or downward data points indicate a trend independent of intervention, whereas a pattern with minor variations is a stable baseline pattern (Barlow & Hersen, 1984). Baseline data

is considered stable if: (a) three consecutive data points are plotted at the same level within the student graph, or (b) a student graph has five data points of which at least three are the same level and the other two vary by no more than one level for the variables of problem solving and estimation, or two levels for math communication. A downward trend is evidenced if: (a) three data points are plotted in which each consecutive data point is one level lower than the proceeding, or (b) a student graph has five to six data points with a consecutive data point drop, e.g., there may be two data points on the same level before continuing the downward trend; the data point drop in this scenario must encompass at least three levels. The intervention was implemented as soon as four students, comprising Group 1, met the above criteria for obtaining a steady state or a downward trend.

During baseline (Phase 1), students continued to receive teacher instruction in math, including word problem solving, that was not altered from the math instruction regularly received. This included teacher directed lessons, strategy instruction, use of basal textbooks, use of manipulatives, practice time on computer using skill-based programs, one-on-one teacher time for individualized instruction and assistance, and take-home work to be completed and graded/reviewed by the teacher.

The following baseline data was collected by the classroom teacher: (a) percentage of correctly solved written word problems, (b) accuracy of communicating mathematics to describe information, and (c) percentage of correctly estimated solutions to math problems.

Percentage of correctly solved written word problems. To assess the percentage of correctly solved word problems, students completed a written, non-contextualized worksheet containing three math word problems each school day. Prior to beginning the research, the classroom teachers provided a student textbook and samples of class word problem solving work to the researcher. Based on this information, the researcher developed a pool of 90 similar problems of comparable difficulty, all of which: (a) required 1- or 2-steps to solve, (b) contained 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) were previously unencountered by the students. The researcher and teachers reviewed the problems together to ensure the problem criteria were met.

These problems were randomly divided into 30 sets of three problems per set. Problems were typed on sheets of paper and pulled from a paper bag for placement into each set. The first three drawn became problem set one, the next three problem set two, and so forth until 30 problem sets were established. Each set of three problems was typed onto a single worksheet and included room for students to show their work. Students worked one set per day as long as they remained in baseline. Problems were read aloud to students as needed. The students were scored as providing a correct response or an incorrect response to each problem. The percentage of problems correct is graphed in Phase 1 of student’s word problem solving graph, titled “Word Problem Solving” and found in the Results section of this paper. No partial credit was given and only the final answer was assessed. Students had no access to any of the data graphs reported in this study at any time. The classroom teacher conducted the assessment of word problem solving and the researcher plotted the corresponding graphs.

Accuracy of communicating mathematics to describe information. Each day in baseline, math communication skills were measured by selecting one of the three word problems described above. On day one, problem one from the problem set was selected, on day two, problem two was selected, and on day three, problem three was selected. These problems are starred on the word problem solving worksheet. On day four the cycle reverted back to problem one, continuing in this manner throughout Phase 1. Please note: the problem did not have to be solved correctly to be used. The student described how s/he attempted to solve the selected problem, based on the prompt:

> *Tell me in one or two sentences how you figured out the answer to Question _ (1, 2, or 3). Do NOT use numbers in your explanation.*

For example, in the following word problem the student might answer as follows:

> *Question 1: Fizz has two reports to give to the class. If his total score on both reports is less than 140 points, he will have to go the principal's office. His first report was on frogs. He got a 58. On his second report he did better and got an 80. What is his total score?*
>
> *Student work: 50 + 80=138*
>
> *Teacher prompt: Tell me in one or two sentences how you figured out the answer to Question 1. Do NOT use numbers in your explanation.*
>
> *Student response: I added the score on Fizz's frog report to the score on his last report to find his total score.*

The student's mathematical communication skills were scored using the scoring rubric, titled Assessing Mathematical Communication (see Table 3), which requires: (a) complete, clear sentences, (b) specific and accurate word phrases (instead of numbers), and (c) description each step of the computation process. Student scores can range from 0-6 points. The above response would receive a 6 because it: (a) uses complete, clear sentences (all of the time - 2 points), (b) uses specific and accurate word phrases instead of numbers (all word phrases specific and accurate – 2 points), and (c) describes each step of the computation process, including operations used, units operated on, and results (description is complete – 2 points). A student could still receive a score of 6 if the answer to the actual problem was incorrect, as long as the criteria within the scoring rubric were met. For further examples of student responses and their corresponding rubric scores, see Table 3.

On day one both the classroom teacher (Jeanie Frasier) and the researcher completed a scoring rubric for each of the eight students and an inter-rater reliability was established. The reliability is the percentage of times in which both observers agreed upon an answer and is noted in decimal form. For the remaining days in which the student is in baseline the teacher conducted the math-communication assessment. The researcher graphed the math communication data points and conducted once-weekly inter-rater reliability assessments as described above for the duration of the study. To review the inter-rater reliability data for the math communication rubrics, refer to Table 5.

Percentage of correctly estimated solutions to math problems. Estimation skills were assessed during baseline utilizing the same types of problems found in "The Estimation Game", provided with the software program. A sample question from Episode 1 is:

Allowance: $1.75

Babysit: $1 or more

Walk dog: $2.50

Tutor: $1.15

Does Martina earn $5 or more every week?

The researcher developed a series of 117 similar problems. The problems: (a) require 1- or 2-steps to solve, (b) contain 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) end with a close-ended question that can be scored as correct or incorrect. An independent evaluator, who is a classroom instructor at The Winston School, reviewed the problems for the above criteria and compared them with those provided in the software program to ensure similarity. Problems were typed on sheets of paper and pulled from a paper bag for placement into each set, with sets drawn in the same manner described above for written word problems (the first three drawn become problem set one, the next three problem set two, etc.) until 34 sets were developed. Problem sets one through nine were placed in reserve for use during the generalization and maintenance/extended generalization phases of the study. The remaining 30 sets were used, in numerical order, for baseline. The students worked one set per day as long as they remained in baseline.

Students solved three estimation problems (one set) per day and had three minutes to complete the set of problems, which proved to be an ample amount of time. Again, problems/words were read aloud to students who needed this modification. Student responses were scored correct or incorrect; “no response” was scored incorrect. Percentage of problems correct was graphed in Phase 1 of the student’s estimation graph, titled “Estimation”. No partial credit was given. Students did not have access to the data graphs. The classroom teacher conducted the daily estimation assessment, with the researcher plotting the graphs.

Intervention. After the baseline data attained a steady state (Sidman, 1960) for four students, Phase 2, intervention, was implemented. Phase 2 was researcher-presented and the researcher conducted all assessments during this phase, unless otherwise noted. The classroom teacher was not involved in this phase of study and the students participated in the study in place of their regular math instruction. While in Phase 1 students participated in their regular classroom instruction (with the exception of the baseline assessments) Phase 2 utilized Fizz and Martina’s “Blue Falls Elementary” computer simulation problem solving software (Tom Snyder Productions, 1998). This program consisted of an introductory activity and four simulation episodes that address the targeted areas of estimation, applied problem solving, and mathematical communication. (For further information regarding this software, refer to the “Software Description” section above). The computer simulation software manual suggests that the program be used with groups of students so that students may discuss problems and potential solutions with one another as part of the learning process. The eight-student referral pool was divided into two groups based on baseline data. Baseline data was gathered until stable for four students at which time those students began the intervention phase (Phase 2) as Group 1. Once baseline data points were stable for the remaining four students (Group 2), Group 2 began the intervention phase, replicating the study across groups and increasing confidence in the reliability of the results. Accuracy rates for contextually presented word problems, mathematical communication ability, and estimation ability were each be measured during Phase 2.

Percentage of correctly solved contextually presented word problems. To assess problem solving accuracy rates, after students viewed each vignette they attempted to solve software program provided word problems. There are two problems per vignette, plus one practice problem in the homework follow-up activities. However, the Intro activity only consists of one problem, therefore problems 10 and 11 of the homework were assessed as the remaining two word-problems. Although these two word problems ask the students to describe how they would solve a problem, students were also asked to solve the problem for data gathering purposes. The students were able to discuss as a group the best approach to take to solve the problems presented after each segment of the vignette. However, each student was accountable for his/her own answer to the problem. Despite group discussion, students often arrived at different solutions. The homework problem was worked independently while still in the classroom. For each problem, the student was scored as providing a correct or incorrect response, and the percentage of problems correct was recorded. No partial credit was given and only the final answer was assessed. Students did not have access to the data graph.

Accuracy of communicating mathematics to describe information. To measure mathematical communication ability, the students were asked to write, in complete sentences, how they figured out the answer to the problem presented within the vignette on their software provided worksheet. As students were asked to do this multiple times during each instructional episode, the first math communication assessment in each instructional episode was used for data gathering purposes. Each student described the steps s/he took to arrive at a solution. As a modification, students were also able to verbally dictate all or part of their answer to the researcher and receive assistance in writing the answer if needed. The students' ability to communicate mathematical terms and methods to describe how the math problem was solved is assessed using the scoring rubric found in Table 3.

A measure of inter-rater reliability between the researcher and the classroom teacher was established for the scoring rubric on the first day of the intervention phase with Group 1, strengthening confidence in the accuracy of the assessment. It was estimated that the Intervention Phase of the study would take one to two weeks to complete, with students working through a total of five vignettes (one introductory and four instructional episodes).

Percentage of correctly estimated solutions to math problems. Estimation ability was assessed using "The Estimation Game", a software presented activity that is a part of the overall software program. In "The Estimation Game", students develop a strategy to estimate good answers to three problems for each of the four vignettes. A sample question from Episode 1 is:

Allowance: $1.75

Babysit: $1 or more

Walk dog: $2.50

Tutor: $1.15

Does Martina earn $5 or more every week?

After listening to the question read aloud by the computer and at the same time viewing the question on the screen, students were encouraged to answer the question within 10 seconds, although more time could be given if needed. In this study, no more than one minute per question was allotted, with average time needed provided in the results section. After answering the question, students shared their various estimation strategies, including those that did not work. Finally, the computer demonstrated the use of an effective strategy. The students were scored as proving a correct or incorrect answer to each problem, and percentage of problems correct was recorded via the estimation data graph, titled "Estimation". No partial credit was given and students did have access to the data graphs.

Generalization. As the intervention was based on the "Blue Falls Elementary" simulation software, when students complete the final episode (Episode 4) and its activities, the intervention ended. On the school day following the completion of Phase 2, students entered Phase 3 of the study, generalization. Students resumed regular math instruction, as decribed in the baseline section of this chapter, with their normal teacher at this time and had no additional instruction from the researcher during this or the following phase. However, assessments in both Generalization and Maintenance were conducted by the researcher. Students were assessed to determine if word problem solving accuracy, estimation ability, and math communication gains seen during intervention (if any) generalized to a non-contextualized traditional written word-problem format. Five probes, each containing a word problem set and a timed estimation problem set, were presented to each student over a period of five consecutive school days. Problems within these sets are static (written on worksheets) rather than dynamic ("Blue Falls Elementary" computer presented adventures, with consequences provided as the math dilemma unfolds).

Percentage of correctly solved written word problems. Prior to beginning the Generalization phase, the researcher developed 27 word problems based on the students' textbooks/normal class work which met the following criteria: (a) required 1- or 2-steps to solve, (b) contained 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) were previously unencountered by the students. The researcher reviewed the problems with the classroom teachers to ensure the problem criteria were met. These problems were developed into nine problem sets. Problems were typed on sheets of paper and pulled from a paper bag for placement into each set. The first three drawn became problem set one, the following three problems became problem set two, etc. until nine problem sets were established. Each set of three problems was typed onto a single worksheet with room included for students to show their work. The first five of the word problem sets were used for assessment during Phase 3 of the study, generalization. The remaining four word problem sets were used during Phase 4 of the study, maintenance. Upon entering Phase 3 of the study, the student solved three of these problems (one set) per school day for five days total. At the conclusion of the fifth day, Phase 3 ended. Each problem was scored as correct or incorrect, with no partial credit given. The researcher administered the worksheets and plotted the percentage of problems correct in the Phase 3 section of each student's "Word Problem Solving" graph. Students did not have access to the data graph.

Percentage of correctly estimated solutions to math problems. As described in the baseline section of this chapter, prior to the onset of the study the researcher developed a series of estimation problems that: a) require 1- or 2-steps to solve, (b) contain 2- and 3-digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, (c) end with a close-ended question that can be scored as correct or incorrect, and (d) are similar to the types of problems presented by "The Estimation Game" section of the software program. Two independent evaluators reviewed these problems for the above criteria. The problems were then developed into sets containing three problems per set, with the first five problem sets reserved for use in the generalization phase of the study.

The estimation sets were presented to the students by the researcher along with the word problem sets, with the estimation sets administered first. Students were allowed three minutes to complete each set. As in Baseline, problems/words from both the word problem and estimation worksheets were read-aloud to students who required this additional modification in both the Generalization and Maintenance phases. Student answers to the estimation problems were scored as correct or incorrect; a non-response was scored as incorrect. The researcher graphed the percentage of problems correct in the

Phase 3 section of the student's estimation data graph. Students did not have access to the data graphs.

Accuracy of communicating mathematics to describe information. To assess generalization of math communication ability to a written, non-contextualized format, one problem was selected from the three written word problems described above to assess student ability to use mathematics to describe information, specifically how they arrived at a solution. The student's mathematical communication skills were scored using the rubric provided in Table 3. On day one problem one was selected, on day two problem two, and so forth, cycling back to problem one on day four. The researcher used the prompt:

> *Tell me in one or two sentences how you figured out the answer to Question _ (1, 2, or 3). Do NOT use numbers in your explanation.*

In response to the prompt, each student explained the mathematical processes s/he used to arrive at the answer and the student's math communication ability was assessed using the scoring rubric found in Table 3. The researcher conducted the assessments and graphed the data points. Inter-rater reliability between the researcher and the classroom teacher continued to be assessed for the scoring rubric during the generalization phase, strengthening confidence in the accuracy of the assessment. Once again, students had no access to the data graphs.

<u>Maintenance/Extended Generalization</u>. Phase 4 of the study examined the maintenance of the two dependent variables targeted in generalization, mathematical communication skills and written word problem solving accuracy rates, therefore

establishing extended generalization (or a lack thereof). It also addressed the maintenance of estimation skills. No additional instruction from the researcher occurred during this phase, but the researcher did conduct the assessments and collect the data. Phase 4 for each student began in the school week following the conclusion of Phase 3. Four probes, each containing a word problem set and a timed estimation problem set, were presented to each student over a period of two weeks, at a rate of two per week, with a least a one school day interval between probes. The researcher administered the probes, with the timed estimation set administered first. The researcher graphed all data points.

Percentage of correctly solved written word problems. Prior to the beginning of the Generalization phase, the classroom teacher provided 27 word problems meeting the following criteria: (a) require 1- or 2-steps to solve, (b) contain 2- and 3- digit addition and/or subtraction (with or without regrouping) and/or 1-digit multiplication, and (c) are previously unencountered by the students. These problems were divided into sets, with four sets reserved for use in Phase 4, maintenance. Students completed two sets of these reserved sets per week, with at least one school day elapsing between sets. The researcher administered the assessments. The percentage of problems correct is graphed in Phase 4 of the student's problem solving data graph by the researcher. Students did not have access to the data graphs.

Accuracy of communicating mathematics to describe information. On the days in which the word problem sets were presented during Phase 4, one problem was starred (problem one on day one, problem two on day two, etc.) from each reserved word problem set to assess math communication. In response to the prompt:

Tell me in one or two sentences how you figured out the answer to Question _ (1, 2, or 3). Do NOT use numbers in your explanation.

students orally described the math processes used to determine their answer. Student responses were scored using the scoring rubric found in Table 3. Again in this section the researcher conducted the assessments and graphed the data points in Phase 4 of the math communication graph. Students had no access to the data points.

Percentage of correctly estimated solutions to math problems. Reserved problem sets six through nine, as described in the baseline phase of the study, were administered in the maintenance phase of the study. Students completed two sets of these reserved sets per week, with at least one school day elapsing between sets. The estimation sets were presented to the students by the researcher on the same day as the word problem sets, with the estimation sets administered first. The sets were timed; students had three minutes to complete each set. Student answers to the estimation problems were scored as correct or incorrect; with any non-responses scored as incorrect. The researcher graphed the percentage of problems correct in the Phase 4 section of the student's "Estimation" data graph. Students had no access to the data graphs.

<u>Data Analysis</u>

Data results are presented graphically (Parsonson & Baer, 1978). Graphic analysis allows for continuous data contact and analysis, which is essential in determining when baseline is stable and when to implement Phase 2. In addition, graphic analysis increases ease of data interpretation and analysis for persons not directly involved in the research (Parsonson & Baer, 1978). The multiple number of dependent variables in this study require that more than one graph be constructed per student. These three charts will be: a) the percentage of correctly solved word problems, labeled “Problem Solving”, b) the ability to use mathematics to describe information, labeled “Math Communication”, and c) the percentage of correctly solved estimation problems, labeled “Estimation”. This data is aggregated, based on student groups, per dependent measure. Problem solving accuracy (targeted by research questions 1, 4, and 6), estimation (targeted by research questions 3 and 8) and math communication (targeted by research questions 2, 5, and 7) data will be plotted per session in simple line graph form, with the graph separated by vertical dotted lines into four sections: Phase 1 (baseline), Phase 2 (intervention), Phase 3 (generalization), and Phase 4 (maintenance). Data points will be linked, expressing effects over time and the relationship between the independent variable and the dependent variables (Parsonson & Baer, 1978). Visual inspection will focus on changes in level (a shift in performance at the time that a new experimental phase is implemented), changes in trend (systematic increases or decreases in accuracy levels), and the latency of change as new phases are implemented (Kazdin, 1984).

Utility and Limitations of the Proposed Research

Clearly this study has limitations, outlined below. However, it is important to note that while this study is imperfect it is also seminal. Estimation, which has been ignored in the LD literature base to date, is addressed. Mathematical communication is addressed as a specific component, unusual in LD problem solving intervention literature. In addition, this study examines computer use to assist teachers in providing students with contextualized math problem solving interventions, reflecting NCTM standards and math movements throughout the country. This study will further enhance the research base not only in the field of word problem solving for students with learning disabilities, but also in the area of CAI for these students. Practitioners and professionals in the field of learning disabilities will be able to analyze the students included in the study and the results to determine whether or not this type of intervention would be appropriate in their setting. In addition, the presentation of graphical analysis and in-depth subject descriptor information makes this study easier to replicate as well as more generalizable. However, this study does contain threats to internal validity, external validity, and conclusion validity. This section will present these threats, as well as other possible limitations.

Threats to Internal Validity

Internal validity, confidence that the independent variable is responsible for changes in the dependent variable, is a crucial component to single-subject research. Through a repeated application of the treatment factor, in this case across groups, internal validity can be established (Sidman, 1960). As Kratochwill (1978) noted, internal validity is a prerequisite to the ability to interpret the results of multiple-baseline studies. In this study, internal validity could be affected by a number of factors, including: (a) history and maturation, (b) testing, (c), instability, and (d) instrumentation.

History and maturation. History refers to the possibility that events occurring simultaneously to the intervention are the cause of any changes in the dependent variable. Similarly, maturation refers to the psychological and physical development of subjects that may occur during the span of the study to produce changes in behavior. Maturation is less of a concern, as the entire span of the study is approximately 7-9 weeks, with Phase 2 (intervention) lasting only 1-4 weeks. Both history and maturation are somewhat controlled through the use of a multiple baseline across groups design. As two different groups of students experienced the intervention at two different points in time, one immediately following the other, if results from the intervention replicate across both groups confidence in those results will be strengthened. However, it is possible that some other program or event could have coincided with the math problem solving intervention for Group 1, Group 2, or both groups and impacted intervention results. Other than the intervention and the presence of the researcher as the primary math instructor during intervention, the researcher is unaware of any such events that occurred during the implementation of this research.

Testing. The threat of testing occurs when improvements by students are attributed to be a result of pretesting. However, pretesting occurred until data points were stable, allowing greater confidence that results seen in intervention phase are due to the intervention itself, rather than a result of pretesting or an already occurring trend. This also addresses the issue of instability. Phase 2 of the study is not applied until data points in Phase 1 are stabilized and consistent.

Instrumentation. The final and most severe threat to internal validity in this study lies in the devices used to measure the dependent variables. Inconsistent or unreliable measuring instruments may affect the internal validity of the research. As the measuring devices used in this study are not standardized, and the math communication rubric requires subjective evaluation, instrumentation must be considered a potential threat. To help control for this, consistent measuring devices (word problem solving question worksheets, estimation question worksheets, and the math communication rubric) are used to assess word problem solving accuracy rates and math communication skills. In developing the written word problems (used to chart both word problem solving accuracy as well as to measure students' math communication ability) and estimation problems for the baseline, generalization, and maintenance/extended generalization phases of the study at least two people (researcher and classroom teacher) had to agree that the problems met specified, objective criteria. In addition, as the measurements for math communication require subjective judgment, an inter-rater reliability for the scoring of the rubrics was established (see Table 5). The reliability is the percentage of times in which both observers agreed upon the answer and is noted in decimal form (e.g., .85). This inter-rater reliability was established once at the beginning of baseline, to ensure reliability from the start of the study. It was assessed again once weekly, ensuring that both scoring rubrics were assessed and controlling for observer drift. Recommended levels for inter-rater reliability range from .70 to .90 (Barlow & Hersen, 1984). In this study, if inter-rater reliability had dropped below .90, efforts would have been made to improve the reliability. These efforts could include clarifying the definitions by which observers make judgments, further training observers, or improving the observation conditions (Barlow & Hersen, 1984). It proved unnecessary to take any of these actions. These two control methods help limit the threat of instrumentation to the internal validity of this study.

Threats to External Validity

External validity is the degree to which one can generalize the results of the intervention to other students and settings. The use of a single subject design allows for greater control because the intervention has been replicated across Group 1 and Group 2 (Tawney & Gast, 1984). However, external validity could be impacted by the student sample. The students in this study are not randomly selected, or matched according to general LD category data. Students were chosen because they are accessible, and certainly cannot represent either the entire spectrum of students with learning disabilities aged 9-11 or the "average" components of such a group. This group of students is unique in particular in that they attend a private academy for students with learning disabilities, while the majority of students with identified learning disabilities are educated in public school settings. To improve population validity, a complete description of the relevant demographic and diagnostic variables for each subject in the intervention is provided in Table 1(Kratochwill, 1978). These variables include gender, primary language, zip code, age, race, handedness, retention, ADHD diagnosis and whether the student was on medication at the time of the study, measured IQ, measured non-verbal IQ (where applicable), and measured achievement in the areas of broad reading, broad math, calculation, math fluency, and applied problems. Other important descriptor information, such as type of special education placement, geographic location, and specific description of the school where the research was conducted are included in this chapter. In addition, subject selection and exclusionary criteria are described (see the Teacher Referral Form in Table 4), as recommended by Morris, Lyon, Alexander, Gray, Kavanagh, Rourke, & Swanson (1994) and Wolery & Ezell (1993) when conducting single-subject research. Including these criteria and descriptors improves external validity (CLD Research Committee, 1992; CLD Research Committee, 1994; Hammill, et al., 1989; Morris, et al., 1994; Wolery & Ezell, 1993) and allows classroom teachers wishing to implement a similar intervention to compare group composition prior to making a decision on whether or not to use the same approach as is applied in this study.

It is also possible that external validity could be jeopardized by the interaction of the baseline assessment with the treatment. This could limit generalizability for groups of students who do not receive such an assessment before the intervention is begun (Campbell & Stanley, 1966). Classroom teachers and researcher attempting to replicate the research would have to consider this as a factor before implementing a similar intervention.

Threats to Conclusion Validity

Conclusion validity, the degree to which one can assume the reported effects of the study are a true reflection of the study's impact, is also somewhat limited due to the use of graphic analysis to present the data from the study. Visual inspection, or graphic analysis, is the primary method used in evaluating single-subject research (Barlow & Hersen, 1984). There are concerns associated with this form of data analysis. The lack of systematic rules for determining when an effect is demonstrated allows for subjectivity on the part of the researcher in determining whether or not the independent variable impacted the dependent variables. In addition, inconsistency in the evaluation of the research effects may develop when persons outside the study view the research results (Kazdin, 1984). While this is true, it is important to note that the method of graphic analysis of the data considers effects to be significant only if the change shown is marked. Effects labeled as statistically significant if statistical analyses were performed might not appear significant through the use of graphic analysis (Murphy & Bryan, 1980; Parsonson & Baer, 1978). Therefore, the primary weakness in the conclusion validity is the possibility of ignoring effects that might be statistically significant. If significant effects are demonstrated through visual inspection, they are, by nature, extreme enough to warrant investigation (Parsonson & Baer, 1978).

Despite threats to internal, external, and conclusion validity, this research is important to the field of learning disabilities in the area CAI word problem solving instruction. The results in this study further examine the use and effects of CAI for students with LD. They begin to determine whether a contextually presented computer simulation is helpful to students in improving word problem solving skills. These results are significant in themselves. However, this study goes further, examining in depth the issue of math communication and how such a software program might impact it. Finally, estimation, which has been ignored as a dependent variable in math problem solving literature to date, is examined in this study.

Chapter Four - Results

The purpose of this study was to examine the effects of a computer simulation program, Fizz & Martina's Math Adventures "Blue Falls Elementary" (Snyder, 1998), on the ability of students with LD to communicate mathematically, estimate problem solutions, and solve applied story problems. This chapter describes the research findings including a) a review of the research questions, b) data graphs and analysis and c) a summary of the results. Please note that when the first three chapters of this dissertation were approved by the researcher's committee, the classroom teachers were going to administer the data collection probes to the students, as well as assess their math communication ability utilizing the scoring rubric found in Table 3, for both the generalization and extended generalization/maintenance phases of the study. However, it was determined that having the researcher administer all probes for these phases within the study was more conducive to regular classroom instruction continuing in a per usual manner. Chapter three has been amended to reflect this change in procedure.

Review of Research Questions

The research examined the following research questions:

What impact will instruction using the "Blue Falls Elementary" program have on:

1. The percentage of correctly solved contextually presented math simulation problems?

2. The accuracy of communicating mathematics to describe information regarding the methodologies applied to solve mathematical problems.

3. The percentage of correctly estimated solutions to presented math problems?

4. Will math problem solving generalize to written story problems, presented in a non-contextualized format?

5. Will the ability to communicate mathematical information generalize to written story problems, presented in a non-contextualized format?

6. Will the percentage of correctly solved written word problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

7. Will the percentages of communicating mathematics to describe information attained during the intervention phase of the study be maintained two weeks after the generalization phase of the study?

8. Will the percentage of correctly estimated solutions to presented math problems attained during the intervention phase of the study be maintained for two weeks following the generalization phase of the study?

Data Graphs and Analysis

Data was collected across four stages (baseline, intervention, generalization, and maintenance/extended generalization) for two groups. Data was collected for three major data graph sets across these four stages: (a) accuracy rates for contextually presented word problems, titled "Word Problem Solving" (Research Questions 1, 4, and 6), (b) estimation ability, titled "Estimation" (Research Questions 3 and 8), and (c) mathematical communication ability, titled "Math Communication" (Research Questions 2, 5, and 7). For each of these graph sets there are two data graphs presented, one for Group 1 and one for Group 2.

Insert Graphs 1A, 1B, 1C and 2A, 2B, and 2C about here

Baseline

Group 1. Group one consists of students 1, 3, 4, and 8. These students remained in Baseline for five days. Students 1 and 8 consistently demonstrated a steady state of performance on all three data graph sets. Students 3 and 4 each evidenced downward performance trends in both estimation and word problem solving ability. Math communication was at a steady state for all students in Baseline, as every student received a zero on the scoring rubrics for this variable each time it was assessed during Baseline.

Group 2. Group two consists of students 2, 5, 6, and 7. These students remained in Baseline for seven days. Baseline data for estimation and problem solving became stable (five data points of which at least three are the same level and the other two vary by no more than one level) for all students in Group 2 by Day 7 of Baseline. No students showed upward or downward trends in estimation or problem solving performance. As mentioned, math communication was at a steady state for all students in Baseline, with Group 2 also receiving zero on the scoring rubrics for this variable each time it was assessed.

Intervention

Problem Solving. The problem solving abilities of students within the study appeared to either remain consistent when the intervention was applied (Students 1, 3 and

8) or presented an upward trend (Students 2, 5, 6 and 7). While Student 4 appears to be entering an upward trend, his mean performance is comparable to baseline. Overall, the use of the intervention appeared to have positive impact on the problem solving abilities of approximately half of the students who participated in the study (Research Question 1).

Group 1. Group 1 consists of students 1, 3, 4, and 8. Students 1 and 8 demonstrated a steady state of performance in Baseline. This steady state continued throughout the intervention. Students 3 and 4 had evidenced a downward trend in baseline. During intervention, this trend appeared to be entering reversal for student 3. Although the mean performance level did not change the data graph shows a trend toward improvement on this variable. Student 4 showed variable performance during Intervention; overall mean performance did not vary from Baseline.

Group 2. Group 2 consists of students 2, 5, 6, and 7. All students demonstrated a steady state in this variable in Baseline with five data points of which at least three are the same level and the other two vary by no more than one level. However, the baseline performance of all four students looks somewhat erratic when viewed graphically. Problem solving performance for each student in Group 2 in Intervention demonstrates an upward trend, with the students showing both improvement as well as more consistent performance. Student 2 showed marked improvement, scoring 100% correct on all problem solving assessments except for one. Students 5 and 6 also showed improvements evidenced graphically by upward trend in performance, consistently scoring either 2 or 3 of 3 on all assessments. In Baseline, these students each scored below this level on one or more days. Student 7 evidenced a similar trend as students 5 and 6, but was absent for two days of the intervention.

Estimation. After listening to an estimation question read aloud by the computer and at the same time viewing the question on the screen, students were encouraged to answer the question within 10 seconds, although more time could be given if needed. Students were able to answer the question within the allotted time frame, although each group asked at least one time to repeat the question. As with problem solving, the estimation abilities of students participating in the study appeared to either remain consistent when the intervention was applied (Students 1, 2, 4, 5, 6, 7 and 8) or present an upward trend (Student 3). Overall, the use of the intervention appeared to have minimal impact on the already consistent estimation performance of the students who participated in the study (Research Question 3).

Group 1. Students 1, 4, and 8 demonstrated a steady state of estimation performance in Baseline, and this state continued during the intervention. As in problem solving, student 3 presented a downward trend in Baseline which reversed itself with consistently improved performance in Intervention for the component of estimation.

Group 2. All students in Group 2 demonstrated a steady state of performance in Baseline when estimation abilities were assessed. This steady state of performance continued for all students in Group 2 at the same levels as evidenced in Baseline.

Math communication. While the math communication component measured in this study required subjective evaluation, the use of a scoring rubric presents a common standard of performance for instructional groups, which can enhance objective evaluation

(Luft, 1998, cited in Prestidge & Glaser, 2000; Prestidge & Glaser, 2000). To enhance the reliability of the findings regarding math communication an inter-rater reliability between the researcher and a classroom teacher was established for the scoring rubric. This reliability is the percentage of times in which both observers agreed upon an answer and is noted in decimal form. This reliability assessment was conducted on day one of baseline, and once weekly for the remainder of the study. To review the inter-rater reliability levels for the math communication rubrics, refer to Table 5.

Insert Table 5 about here

During Intervention, math communication did not appear to be significantly improved or affected when assessed with the software provided scoring rubric, with the majority of students continuing to receive primarily zeros on this measure when assessed (Research Question 2).

Group 1. Student 1 presented minimal evidence of an upward trend in math communication, while all other students (3, 4, and 8) remained at a steady state.

Group 2. Student 6 presented beginning evidence of an upward trend in math communication during the intervention stage of the study. All other students in Group 2 remained at a steady state, although student 5 had one outlier in a positive performance direction.

<u>Generalization</u>

Students were assessed to determine if word problem solving accuracy, estimation ability, and math communication gains seen during Intervention (if any) generalized to a non-contextualized traditional written word-problem format. Five probes, each containing a word problem set and a timed estimation problem set, were presented to each student over a period of five consecutive school days, with times estimation sets administered first. Problems within these sets were static (written on worksheets) rather than dynamic.

Problem solving. Generalization results in the area of problem solving were mixed (Research Question 4). As Students 1 and 8 continued their steady state of performance, only Student 3 presented evidence of Generalization in Group 1, with erratic performance by Student 4 during the Generalization phase of the study. Group 2, however, demonstrated generalization to a paper-and-pencil format across all students within the group (Students 2, 5, 6, & 7).

Group 1. The graphs demonstrate some erratic performance in this group in the Generalization phase of the study. For example, Student 1 maintains a steady state of performance, except for an outlier on Day 12, when he receives one of three on the problem solving set, the only time his performance has dropped to that level. Student 4 has erratic performance as well, with perfect scores on Days 12 and 15, and a zero on Day 13. Student 3 also shows fluctuating performance, and the beginning upward trend shown during Intervention drops, then reappears. Only Student 8 shows a consistent steady state. Graphically, only Student 3 demonstrates that performance skill gains evidenced in Intervention have transferred to a paper-and-pencil format. However, as the mean performance level appears to be similar to baseline in is difficult to conclusively determine that generalization has occurred.

Group 2. Group 2, interestingly, performed very differently than Group 1 did in this phase of the study. The upward trends evidenced in Intervention were maintained by all students (2, 5, 6, and 7) during the generalization phase of the study. This, coupled by the erratic performance of these students when in baseline, suggest that the Intervention not only improved problem solving performance for this group of students, but that these improvements in problem solving abilities transferred to a static, paper and pencil problem solving format. That these results are replicated across the entire group of students strengthens the reliability that the problem solving improvements seen during Intervention did indeed generalize for Group 2.

Estimation. Previously developed written estimation sets, consisting of three problems per set, were used to asses this variable during the Generalization phase of the study. The estimation sets were presented to the students by the researcher along with the word problem sets, with the estimation sets administered first. Students were allowed three minutes to complete each set. Problems were read-aloud to students who required this additional modification. Student answers to the estimation problems were scored as correct or incorrect; a non-response was scored as incorrect. Estimation skill gains evidenced during Intervention transferred to a paper-and-pencil format for the majority of students participating in the study. Students primarily demonstrated either a steady state of performance following the Intervention (Students 1, 3, 4, and 8) or a slight to more marked upward trend (Students 2, 6 and 7) in performance for this variable during the

Generalization phase of the study. Only Student 5 demonstrated a downward performance trend on the estimation assessments during Generalization.

Group 1. Students 1, 4, and 8 maintained steady state in the generalization assessments of their estimation skills. Students 3 continued to demonstrate the improved performance evidenced in the upward performance trend from Intervention, except for Day 14 on which the student scored a zero on the estimation measure. In light of the erratic performance of this group in the problem solving portion of this phase in the study, it is interesting to note that all students except student 8 had one outlier in otherwise steady performance. The outlier for student 4 may be indicative of a student drop in performance. Thus, while it appears that estimation skill gains for student 3 have transferred to a paper/pencil format, there is no evidence to indicate that generalization in estimation has occurred as a result of the application of the Intervention for the remaining students in Group 1.

Group 2. All students in group 2 evidenced a steady state of performance in estimation skills in both Baseline and Intervention. Interestingly, the majority of students in Group 2 (students 2, 6, and 7) appear to evidence a slight upward trend in the generalization segment of this study. However, student 5 evidences a downward trend after a steady high level of performance in both baseline and intervention. It does appear that the intervention has impacted student ability to solve estimation problems in a paper and pencil format, with slight performance increases for students 2, 6, and 7 and more striking performance decrease for student 5.

Math Communication. In the intervention phase of the study, students were presented a contextualized problem, orally discussed the problem, and then wrote one or more sentences to describe how they arrived at the problem solution. To assess generalization of math communication ability, one problem was selected from the three written word problems described above. Students were asked to orally respond to the prompt, "*Tell me in one or two sentences how you figured out the answer to Question _ (1, 2, or 3). Do NOT use numbers in your explanation.*" The students' verbal responses were written down and scored at a later time using the rubric provided in Table 3. Math communication performance during the first two phases of the study was almost non-existent. Interestingly, during Generalization all students demonstrated an upward trend in math communication skills as measured by the scoring rubric (Table 3). This trend, replicated across all students within the study, indicates that the intervention did have an impact on math communication skills (Research Questions 2 and 5) as they are assessed during Generalization.

Group 1. Group 1 showed a steady state of non-performance in baseline, and this trend continued in Intervention for all students except student 1, who showed a slight increase in performance. During the Generalization phase of the study, a significant increase in the math communication abilities of all students in Group 1 was evidenced. Student 1 continued the upward trend in evidence at the end of intervention to the highest level of math communication performance within this group. Students 3, 4, and 8 all also evidenced significant performance gains in this component. Therefore it appears that the intervention did have an impact on math communication for Group 1, as evidenced in the generalization assessments requiring students to orally describe solution strategies to written word problems.

Group 2. Similar to Group 1, Group 2 had a steady state of non-performance in the baseline assessments of math communication, with this trend continuing in Intervention for all students except student 6, who showed a slight upward trend. Again, the math communication performance increases in Generalization demonstrated by Group 1 were also evidenced by Group 2. All students in Group 2 showed significant increases in their math communication ability as assessed by the scoring rubric in Table 3. While Student 2 demonstrates varied performance and Student 5 has an outlier, all students in Group 2 demonstrate upward performance trends. The data graph indicates that the intervention again had a positive impact on math communication, as evidenced in the generalization assessments. This assertion is strengthened by the replication of these results across both groups of students participating in the study.

Maintenance/Extended Generalization

Phase 4 of the study examined the maintenance of the two dependent variables targeted in generalization, mathematical communication skills and written word problem solving accuracy rates, therefore establishing extended generalization (or a lack thereof). It also addressed the maintenance/extended generalization of estimation skills. Phase 4 for each student began in the school week following the conclusion of Phase 3. Four probes, each containing a word problem set and a timed estimation problem set, were presented to each student over a period of two weeks, at a rate of two per week, with a least a one school day interval between probes. The researcher administered the probes, with the timed estimation set administered first. Words/problems were read aloud to students as needed.

Problem solving. In the same manner as in Generalization, during Maintenance/Extended Generalization previously developed written word problem sets, consisting of three problems per set, were presented to the students. As during Generalization, Group 1 demonstrated limited evidence of extended generalization to a paper-and-pencil format. Student 4 did demonstrate the performance increase which began appearing during generalization, indicating that generalization and maintenance did occur for this student. Group 2 continued to demonstrate generalization of the performance gains seen during Intervention demonstrating maintenance/extended generalization (Research Question 6).

Group 1. The data graphs of students 1 and 8 continue to show a steady state of performance in the area of problem-solving, which is not surprising as this state of performance has been demonstrated throughout the study. After an upward trend during Intervention and erratic performance during the Generalization phase of the study, Student 3 demonstrated a steady level of performance, with an outlier on the final day of 3 of 3 written-word problems correct. As in Generalization, Student 3 presented a mean performance level commensurate with his performance during Baseline; therefore it is difficult to say that generalization and maintenance occurred, although he upward trend demonstrated during the Intervention has been maintained. However, Student 4, who had presented erratic graph results during Generalization demonstrated an upward performance trend during Maintenance/Extended Generalization. This appears to indicate that generalization of the improvements that began to be evidenced during Intervention for Student 4 did occur and that these results were maintained until the conclusion of the study.

Group 2. As during Generalization, the upward trends evidenced in Intervention were maintained by all students (2, 5, 6, and 7) during the Maintenance/Extended Generalization phase of the study. All students in this group showed a consistent, high level of performance up to three weeks past the application of the Intervention, indicating that the positive impact in the area of problem solving demonstrated during the intervention not only generalized to a static format but that these results were maintained for an extended period of time. These results were replicated across all four students in this Group, strengthening the assertion that Generalization and Maintenance/Extended Generalization did occur for Group 2.

Estimation. In the same manner as in Generalization, during Maintenance/Extended Generalization previously developed written estimation sets, consisting of three problems per set, were presented to the students. Students were allowed three minutes to complete each set. Problems were read-aloud to students who required this additional modification. Student answers to the estimation problems were scored as correct or incorrect; a non-response was scored as incorrect. Students completed these problems prior to being given the word problem sets to solve. Student 3 was the only student with performance gains that appeared to generalize and be maintained for this variable. As a whole, neither Group 1 nor Group 2 had results significant enough to indicate that Maintenance/Extended Generalization occurred for the variable of estimation (Research Question 8).

Group 1. Students 1, 4, and 8 continued to demonstrate a steady state on the graph of estimation performance. Student 4, who had one outlier to the other wise steady performance during Generalization, again had one outlier during Extended Generalization. However, this student's overall performance on the estimation measures was steady. Graphically, it appears that the improvements demonstrated during Intervention for Student 3 did generalize to a paper-and-pencil format and that these improvements were maintained for an extended period of time, although overall performance was not as consistent as evidenced during Intervention. However, the lack of replication of this performance trend across the other students in this group, coupled with Student 3's initial performance on the first two probes in baseline (perfect scores prior to the beginning of a downward trend) make it difficult to assert that the use of the Intervention resulted in gains in estimation skills.

Group 2. While Group 2 demonstrated some slight shifts in performance during the Generalization phase of the study, overall their performance on the estimation measures was steady. Student 2, who had evidenced a slight upward trend in Generalization, showed a slight downward trend in Extended Generalization; however, if you view the performance graph as a whole, Student 2 demonstrated steady performance. Similarly, Students 6 and 7 both evidenced slight upward trend in Generalization which were maintained in a steady state in Extended Generalization, but when viewed as a whole their overall performance evidenced a steady state. Finally, student 5, who evidenced a downward trend in Generalization, reversed this trend during Extended Generalization with an upward trend in performance. However, this upward trend placed the student's performance back at the initial performance level. Thus there is no evidence that estimation skills were impacted in either a positive or negative manner by the use of the Intervention.

Math Communication. As in the Generalization phase, to assess extended generalization of math communication ability, one problem was selected from the three written word problems described in the Problem Solving section above. Students were asked to orally respond to the prompt, "*Tell me in one or two sentences how you figured out the answer to Question _ (1, 2, or 3). Do NOT use numbers in your explanation.*" The students' verbal responses were written down and scored at a later time using the rubric provided in Table 3.

As during the Generalization phase, during Maintenance/Extended Generalization all students across both Groups continued to demonstrate an improved ability in the variable of math communication which was maintained for three weeks following the conclusion of the intervention, further strengthening the assertion that the intervention positively impacted math communication skills Research Question 7).

Group 1. Performance levels for Group 1 remained well above the baseline and intervention levels. Student 4 demonstrates a steady state with a downward outlier. Students 1, 3 and 8 continue the steady improved state of performance demonstrated in the Generalization assessment of this variable. Overall, it appears that performance gains in math communication evidenced in the Generalization phase of the study continued through the two weeks that extended generalization was measured.

Group 2. Group 2 also maintained the performance gains demonstrated during Generalization. It is interesting to note that while students 2 and 5 demonstrated an upward trend in Generalization their performance was erratic, with each student receiving at least one zero when math communication was assessed during Generalization. However, the assessment results during Extended Generalization were much more consistent for these two students. In fact, all students in this group showed a steady rate of performance in Phase 4 of the study, at a level significantly above the performance demonstrated in both baseline and intervention. Thus it appears that gains evidenced in Generalization continued to be demonstrated during Extended Generalization. The Extended Generalization results continue to demonstrate that the intervention had a positive impact on math communication as measured in the final two phases of the study. Again, this assertion is strengthened by the replication of these results across both groups of students participating in the study.

Results Summary

As detailed in the previous section, data across two groups was collected for three major variables: (a) accuracy rates for contextually presented word problems, titled "Word Problem Solving" (Research Questions 1, 4, and 6), (b) estimation ability, titled "Estimation" (Research Questions 3 and 8), and (c) mathematical communication ability, titled "Math Communication" (Research Questions 2, 5, and 7). A summary of the results for each of these sets is presented below.

Word Problem Solving

Overall, the use of the intervention appeared to have positive impact on the problem solving abilities of approximately half of the students who participated in the study, with performance gains generalizing to a paper-and-pencil format for all students who demonstrated positive performance gains in Intervention and lasting for the three weeks of assessments following the intervention for all of these students but one. Four of the eight participating students, all members of Group 2 in the study (Students 2, 5, 6, and 7) demonstrated upward performance trends when the intervention was applied. Students 3 and 4 appeared to halt the downward trends evidenced during Baseline, but the data graphs do not present conclusive evidence of performance gains. The final two students (Students 1 and 8) demonstrated a steady level of performance on this variable across all phases of the study. Of the remaining six students, all but Student 4 demonstrated generalization of the improved problem solving skills to a paper-and-pencil format. While Student 4 had erratic performance during Generalization that made it impossible to determine if generalization occurred, during Maintenance/Extended Generalization he evidenced a steady, upward performance trend which showed that generalization had occurred. In addition to Student 4, Students 2, 5, 6, and 7 also maintained the problem solving skill gains evidenced during Intervention and Generalization.

Estimation

Student 3 presented an upward performance trend during Intervention on the variable of estimation. This apparent skill gain appeared to generalize to a timed paper-and-pencil format and was maintained until the conclusion of the study. Thus, while the Intervention appeared to positively impact estimation skills for Student 3 it is difficult to generalize this assertion as the remainder of students demonstrated a fairly steady state of performance on estimation assessments across all phases of the study with the exception of Student 5 who showed a decrease in estimation performance as measured during Generalization.

Math Communication

Math communication ability, as measured by the Scoring Rubric found in Table 3, appeared to be positively impacted by the Intervention. However, there was a time lag between Intervention and the evidence of performance gains, with only two students (Students 1 and 6) showing the beginnings of an upward trend prior to the conclusion of the Intervention. However, during generalization to a paper-and-pencil/oral question format all the students evidenced upward trends on this variable. These performance gains were maintained until the conclusion of the study for all students except Student 8, whose performance appeared to be declining somewhat, although it was still well above the baseline state. Thus it appears that math communication is positively impacted through exposure to the Intervention and that this impact is generalizable and sustainable as measured in this study.

Chapter Five - Discussion

The use of the Intervention appeared to positively impact math communication skills when assessed during Generalization and Extended Generalization/Maintenance, had mixed results in positively impacting student problem solving abilities, and appeared to have little, if any, impact on students' estimation abilities. The results should be of interest in practical applications for researchers and teachers of students with learning disabilities. This chapter will discuss: a) possible causes for the overall lack of performance gains seen during Intervention, b) math communication performance gains, c) estimation and the relationship of math communication to expressed estimation ability, d) student thoughts and attitude regarding the Intervention, and e) suggestions regarding possible future research. Anecdotal items that relate to the research are included in this chapter.

Lack of Overall Performance Gains During Intervention

While half of the students in the study did present upward trends in problem solving during the Intervention, overall the Intervention produced limited performance gains in problem solving (replicating across four of the eight participating students), no gains in math communication (as evidenced in the Intervention phase of the study) and only one student showed gains in estimation. The estimation measures may have been inappropriate or the students estimation skills may have been stronger than anticipated based on teacher referrals (see more in Estimation and Its Potential Relation to Math Communication, below). One possibility for the overall lack of evidenced performance gains is that the role of the teacher (researcher) as facilitator versus instructor in the application of the program was an ineffective method. Clark (1983; 1994) discusses the role of technology as a media delivery vehicle as opposed to a vehicle for producing change.

The software presents interesting, dynamic problem solving applications in a context which the students seemed to enjoy (see Student Thoughts and Attitudes Regarding the Intervention, below). In analyzing the instructional components of the program, many positive features are in place. Practice problems are presented and worked through via the software. Students are encouraged to talk through the problems they solve, and the characters within the program are seen applying math to their everyday lives. Explanations of how the word problems and estimation problems are solved are shown visually in conjunction with a description of the solution. Independent practice problems are provided to the students. Clearly, this was an effective combination for improving word problem solving skills for half of the participating students within the study.

However, a further analysis of instructional components reveals areas which could be altered for potential improved student performance and which instructors might want to consider in classroom applications of this type of instruction. The intervention is short in length and lacks the direct instruction components that often prove effective for students with learning disabilities (for a fuller discussion of the importance of direct strategy instruction in math word problem solving for students with LD see Wilson & Sindelair, 1991). Designed to last only five days (although the students in this study could not complete the intervention in that time period), students participating in the study were not exposed to a consistent, reinforced model of problem solving. Additionally, the number of instructional problems the students worked during each lesson was fairly minimal, further increasing the need for an extended Intervention period with increased instructional problems and practice. Additionally, although in this research the researcher served as a facilitator only and did not attempt to teach the students how to become better math problem solvers, estimators, or communicators, classroom instructors would want to build in the direct instructional components which are lacking in this Intervention. What would be ideal, although not currently available, would be a series of these math adventures at a consistent instructional level, which the students could revisit periodically throughout the year in combination with specific, targeted math problem solving instruction, spiraling their learning and instruction. For example, the students were never aware of the components within the scoring rubric used to assess math communication. If these components were directly taught and the students had access to their scores/data graphs, student performance on this variable might differ significantly.

Math Communication Performance Gains

Despite the lack of direct instruction in math communication, students did show math communication gains, although not during Intervention. Interestingly, while both groups showed poor performance on the math communication rubrics after the introductory segment of the intervention, anecdotal evidence of improvements could be seen during math communication assessment. For example, in both Groups 1 and 2, all students except for one used the phrase “number of” as part of their description of how they solved the problem. Additionally, several students used the terms “subtract” and/or “borrow”. These improvements in speaking mathematically continued to be evidenced during conversations during instructional time, despite any significant graphical evidence of improvements. There appeared to be a “learning time lag” before students were able to demonstrate performance gains when assessed with the scoring Rubric in Table 3. This time lag may be a result of processing and recall differences for students with learning disabilities (Gettinger, 1991; Robinson, Menchetti, & Torgesen, 2002). For example, when Bauer and Newman (1991) examined recall time across students with and without disabilities they found recall time rates were faster for students without disabilities. A significant improvement in math communication across all students was not evidenced until the generalization phase of the study. However, demonstrated problem solving and estimation skill improvements did not occur on a time lag. This time lag makes it unlikely that the math communication gains evidenced are inter-correlated with the problem solving gains which occurred prior for several of the participating students. However, that is a possibility and should continue to be examined in future research of this manner.

Estimation and Its Potential Relation to Math Communication

Student estimation performance appeared generally strong from the beginning of the study; thus overall estimation skills were not significantly impacted by Intervention. Of the eight students referred in this study, the teacher referral forms indicated that all but Student 8 experienced difficulty with estimation skills in the classroom, but that was not seen by the researcher during the course of the study. This may also be an indicator that the estimation problems developed for the research were not difficult enough (see Table

2, Estimation Item Difficulty Equivalence), or that students should have been presented with a larger number of problems daily or assessed in a different manner.

The only student whose estimation skills appeared to be impacted by exposure to the Intervention was Student 3. Student 3 presented an upward performance trend during Intervention that appeared to both generalize and be maintained. This student also demonstrated performance gains in the area of math communication which generalized and were maintained. While no other data correlation between math communication and estimation skills emerged in the course of this study, anecdotal evidence correlating the two did present itself. During Intervention, one or more students shared how they arrived at their answer to each computer presented estimation problem. As the Intervention progressed, student answers reflected a continued improvement in the ability to communicate mathematically. Examples (unedited) include: “The three presents were about $10 each, that equals thirty, plus thirty-five more is more than $60” (Student 5, Episode 2); “ I rounded each to the nearest dollar, then I added” (Student 6, Episode 2); “Well, first I added 19 and 18 together and that was 37 and there was a dollar (amount) more, so I knew I needed about $50 more” (Student 4, Episode 4); “I rounded 49 to 50 and 176 to 175 and then minused (subtracted) 175 by 50 and got 125” (Student 1, Episode 4). Students were able to speak about math, and about estimating, in a way that was not evidenced prior to the start of the study, according to anecdotal teacher reports. The possible inter-correlation between estimation and math communication is an area that should be investigated further in future research.

<u>Student Thoughts and Attitude Regarding the Intervention</u>

The software manual describes each Instructional Episode being completed in one day (not including Homework). The students labored with many aspects of this Intervention, including the writing required. Often, additional viewing(s) of the video segments or Estimation Game vignettes was required. Each Episode took additional time to complete. This is not surprising, as the software was designed with the general education population in mind, and students with learning difficulties often evidence processing difficulties or slowness in executing operations (Kirby & Becker, 1988). Despite this, students remained primarily attentive and on-task throughout the Intervention. Prior to beginning Episode 3 (the fourth instructional session in the intervention), students in Group 1 spontaneously noted that the sessions seemed "easier than at the beginning" with student 1 noting, "We used perseverance." When Group 2 reached this point in the intervention, they expressed a similar sense of improvement. Student 6 said, "I've learned how to listen and what to listen for." Student 2 said, "I'm encouraged because I thought it was going to be hard." Thus the students appeared to intrinsically feel that their problem solving skills were improving, although they had no access to the data graphs and not all data graphs showed performance gains. This recognition may have encouraged further success, as self-efficacy regarding math ability for students with LD can be a predictor of achievement (Meltzer, Reddy, Pollica, Roditi, Sayer & Theokas, 2004; Pajares & Miller, 1994). One of the NCTM standards discussed in Chapter 1 was "developing confidence in individual mathematic abilities" (NCTM, 1989). While this study did not attempt to address this goal or measure whether it was met, students did appear to become more confident in their problem solving abilities as the intervention progressed even if they did not show significant skill gains.

At the conclusion of the Intervention, each student was asked whether or not they enjoyed the computer-assisted instruction, what they didn't like/would change about the program, and whether they would like to utilize this program or one like it again. All students in both Group 1 and Group 2 said they liked participating in the Intervention and would like to do similar work again. A few of the additional comments were: "There's nothing I didn't like about it—I thought it was James Bond because I liked it" (Student 3); "The characters were not too fictional" (Student 1, referring to the program still being "cool" despite the cartoon characters); "I liked everything but reading over the questions" (Student 7); and "I didn't like the writing part" (Student 2). Student 2 was the only student to mention the amount of writing required, although this is something the students often seemed to labor over during instruction. The positive gains seen in problem solving and math communication, as well as estimation for student 3, may be in part related to the students' willingness to persevere despite perceived difficulty by the researcher for the students during many parts of the Intervention. Overall, students expressed positive attitudes about utilizing the software program and participating in the study.

<u>Future Research</u>

As mentioned earlier, estimation performance appeared generally strong for all but one student in the study, Student 3. This use of the Intervention did appear to positively impact this student's estimation ability as measured by the estimation probes. In addition, the gains appeared to generalize to a timed paper-and-pencil format and were maintained for the three weeks following the conclusion of the Intervention. It would be informative to further examine this variable in future research, perhaps developing an alternate form of assessment or pre-testing students' estimation skills before qualifying them for the study.

In the area of math communication, investigating the correlation, if any, between math communication and estimation abilities would be informative, especially in light of developing teaching strategies. Future applications of this Intervention could also investigate what the impact would be on a student group with higher initial performance levels on the variable of math communication, specifically whether a time-lag in math communication skill gains would present itself and whether the Intervention would still have a significant impact in math communication skills. Also, presenting this research to groups of students with and without learning disabilities might yield additional information regarding the time-lag in demonstrating acquired math communication skills. Additionally, examining the correlations between problem solving and math communication prior to, during, and following research of this type might further illuminate the importance, or lack thereof, of teaching math communication skills to students with learning disabilities in order to improve their problem solving skills. Finally, the development of normed or more widely field tested measures of math communication would be beneficial in conducting future research and in developing teaching strategies for this variable if appropriate.

In the area of problem solving, it would be interesting to investigate whether a longer time period of exposure to the software combined with an increased number of instructional practice problems would positively impact Intervention results. Additionally, a combination of metacognitive strategy instruction in the area of math problem solving alongside participation in this type of instructional software program might yield beneficial results not only in the area of problem solving, but in the other dependent variables as well.

Table 1

Student Demographic and Diagnostic Data

Student	M/F	Language*	Zip Code	Age	Grade	Race	Handedness**	ADHD^	Retention	WISC***	Non-V^^	Broad Math	Calculation	Math Fluency	Appl. Problems	Broad Reading
1	M	E	75025	10y 9m	4	white	L	N	N	102	83	92	84	75	105	59
2	M	E	75019	10y 7m	4	white	R	N	N	105	n/g	92	90	100	94	73
3	M	E	75228	10y 3m	4	black	R	Y (no med.)	N	90	99	n/g	83	85	78	n/g
4	M	E	75160	10y 4m	4	white	L	N	N	104	n/g	88	89	104	85	99
5	M	E	75243	10y 9m	4	black	R	Y (Ritalin)	N	107	96	101	96	100	105	89
6	M	E	75244	10y 0m	4	white	R	Y (Strattera)	N	135	133	123	110	124	120	94
7	F	E	75238	10y 2m	4	white	L	Y(Metadate)	N	96	n/g	91	94	81	92	90
8	M	E	75214	10y 9m	4	white	R	Y(no med)	Y(K)	125	146	103	96	76	117	105

*Language: E=English only, B=Bilingual, ESL=English is a Second Language

**Handedness: L=Left hand dominant, R=Right hand dominant, A=Ambidextrous

***WISC: Students 1, 3, 5, 6, 8 assessed with the Weschler Intelligence Scale for Children - Third Edition (WISC-III); Students 2, 4, 7 assessed with the Weschler Intelligence Scale for Children - Fouth Edition (WISC-IV)

^ADHD: All Attention Defecit Hyperactivty Disorder diagnoses are from a pediatrician except student 6, diagnosed by a clinical psychologist; medications taken are noted

^^Non-V: Non-Verbal IQ; Students 1, 5, 6, 8 assessed with the Test of Non-Verbal Intelligence - Third Edition (TONI-3); Student 3 assessed with the Comprehensive Test of Nonverbal Intelligence (C-TONI)

All achievement scores assessed with the Woodcock-Johnson - Third Edition: Tests of Achievement (WJ-III)

Table 2

Estimation (Baseline, Generalization, Maintenance) Item Difficulty Equivalence

Baseline (Group 1 – Worksheets 1-5; Group 2 – Worksheets 1-7)

Worksheet 1	Mean Difficulty: 1.0
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: 1.0
Problem 3	Item Difficulty: 1.0
Worksheet 2	Mean Difficulty: .92
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: .75
Problem 3	Item Difficulty: .88
Worksheet 3	Mean Difficulty: .90
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: 1.0
Problem 3	Item Difficulty: .71
Worksheet 4	Mean Difficulty: .76
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: .63
Problem 3	Item Difficulty: .75
Worksheet 5	Mean Difficulty: .67
Problem 1	Item Difficulty: .13
Problem 2	Item Difficulty: .88
Problem 3	Item Difficulty: 1.0
Worksheet 6	Mean Difficulty: 1.0
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: 1.0
Problem 3	Item Difficulty: 1.0
Worksheet 7	Mean Difficulty: .83
Problem 1	Item Difficulty: .75
Problem 2	Item Difficulty: 1.0
Problem 3	Item Difficulty: .75

Generalization

Worksheet 8	Mean Difficulty: .79
Problem 1	Item Difficulty: .63
Problem 2	Item Difficulty: .88

Table 2, cont.

Problem 3	Item Difficulty: 1.0
Worksheet 9	Mean Difficulty: .92
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: .88
Problem 3	Item Difficulty: .88
Worksheet 10	Mean Difficulty: .79
Problem 1	Item Difficulty: .75
Problem 2	Item Difficulty: 1.0
Problem 3	Item Difficulty: .63
Worksheet 11	Mean Difficulty: .63
Problem 1	Item Difficulty: .5
Problem 2	Item Difficulty: .63
Problem 3	Item Difficulty: .75
Worksheet 12	Mean Difficulty: .63
Problem 1	Item Difficulty: .88
Problem 2	Item Difficulty: .38
Problem 3	Item Difficulty: .63
Extended Generalization/Maintenance	
Worksheet 13	Mean Difficulty: .83
Problem 1	Item Difficulty: .75
Problem 2	Item Difficulty: .88
Problem 3	Item Difficulty: .88
Worksheet 14	Mean Difficulty: .92
Problem 1	Item Difficulty: .88
Problem 2	Item Difficulty: .75
Problem 3	Item Difficulty: .88
Worksheet 15	Mean Difficulty: .75
Problem 1	Item Difficulty: .5
Problem 2	Item Difficulty: .88
Problem 3	Item Difficulty: .88
Worksheet 16	Mean Difficulty: .92
Problem 1	Item Difficulty: 1.0
Problem 2	Item Difficulty: .88
Problem 3	Item Difficulty: .88

“Item Difficulty” is defined as the percent of students in the current study who correctly answered the item.
“Mean Difficulty” is defined as the overall average percent of correct responses per worksheet.

Table 3

Assessing Mathematical Communication (Snyder, 1998, p. 38)

Uses clear, complete and grammatical sentences

Score	Description
2	All of the time
1	Some of the time
0	Not at all

Uses specific and accurate word phrases in place of numbers

Score	Description
2	All word phrases are specific and accurate *"I multiplied the cost of Martina's weekly dues by the number of weeks she hasn't paid."*
1	Some word phrases are vague or unclear; uses numbers along with word phrases *"I multiplied the dues by the weeks."* *"Her dues are $3, so I multiplied the number of weeks she owes."*
0	Uses numbers instead of word phrases; no answer *"I multiplied 3 by 6."*

Describes each step of the computational process – including operation(s) used, units operated upon, and results

Score	Description
2	Description is complete *"To find out how many games Budge won, I added the number of games he won in his 1st, 2nd, and 3rd seasons."*
1	Description is partially complete *"To find out how many games Budge won, I took the number of games he won in his 1st, 2nd, and 3rd seasons."* *To find out how many games Budge won, I added all three together."*
0	Description is minimal/nonexistent *"I added."*

Table 4

Teacher Referral Form

Please provide me with a list of the students you would like to refer to the study by 1-18-05. Include the students' schedules with your list. Students should meet the following criteria:
Disability: Students must qualify for services as a student with a learning disability. If a student does not have a documented learning disability as identified by Texas School System guidelines, they will be excluded from the study.
Gender: either
Age: 9-11
Current Grade Level: 3-5
Literacy Level: 3rd grade or above. For example, the student should be able to read the following:

> *Martina is saving her babysitting money to buy a pop-up book about Egyptian mummies. The book costs $42. Each week Martina earns $8 babysitting for her neighbor Ellie. Martina hopes she will have enough money to buy the book in one month's time.* (Snyder, 1998, p.51)

If the student needs help with an unfamiliar word (such as Egyptian), this is acceptable. However, if the student would struggle to read a passage such as the one listed above, they should not be referred.
Math skill level: 3rd grade or above.

Addition and Subtraction: Students must be able to add and subtract 2- and 3-digit number with re-grouping. (Proficiency level: 80%)
Multiplication: Students should have rote memory of all 1-digit multiplication facts 0-9. (An overall proficiency level of 90% is recommended, however, if there is a single set of facts which the student has not yet mastered, such as their eights, the student should not be referred for the study).

Difficulty area(s):

Word problems. Word problem solving in 1- and 2-step word problems requiring 2- and 3- digit addition and subtraction and/or 1-digit multiplication. For example, the problem listed above. (Proficiency level: below 70%).
Computational estimation. For example, could the student quickly (with 30 seconds) determine an answer to this problem:

Allowance: $1.75
Babysit: $1 or more
Walk dog: $2.50
Tutor: $1.15

Does Martina earn $5 or more every week? (Snyder, 1998, p. 22)
(Proficiency level: below 70%)

Please note: Referred students must have parent permission in order to participate in the study.

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Referred students: Place a “W” next to the names of students with word problem solving difficulty, an “E” next to the names of students with estimation difficulty, and a “WE” next to students who have difficulty with both.

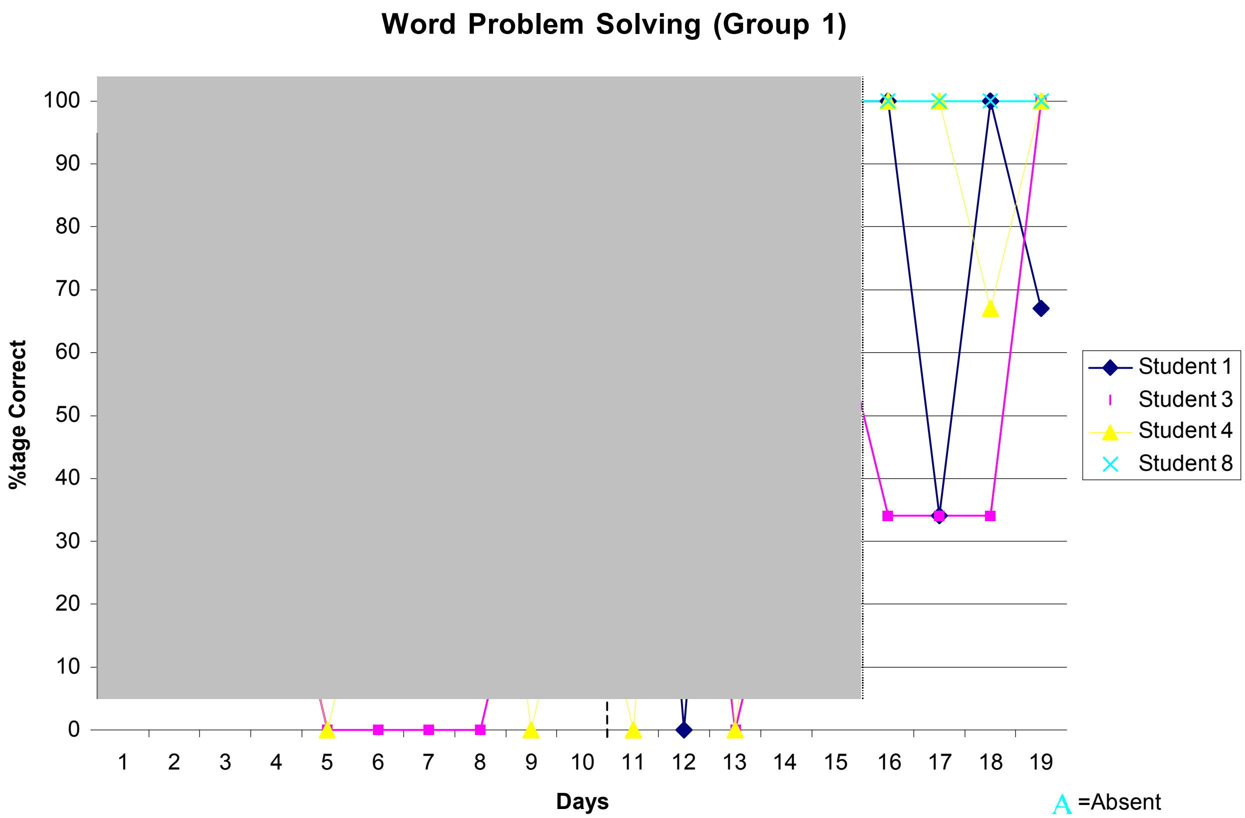
Table 5

Math Communication Inter-Rater Reliability Levels

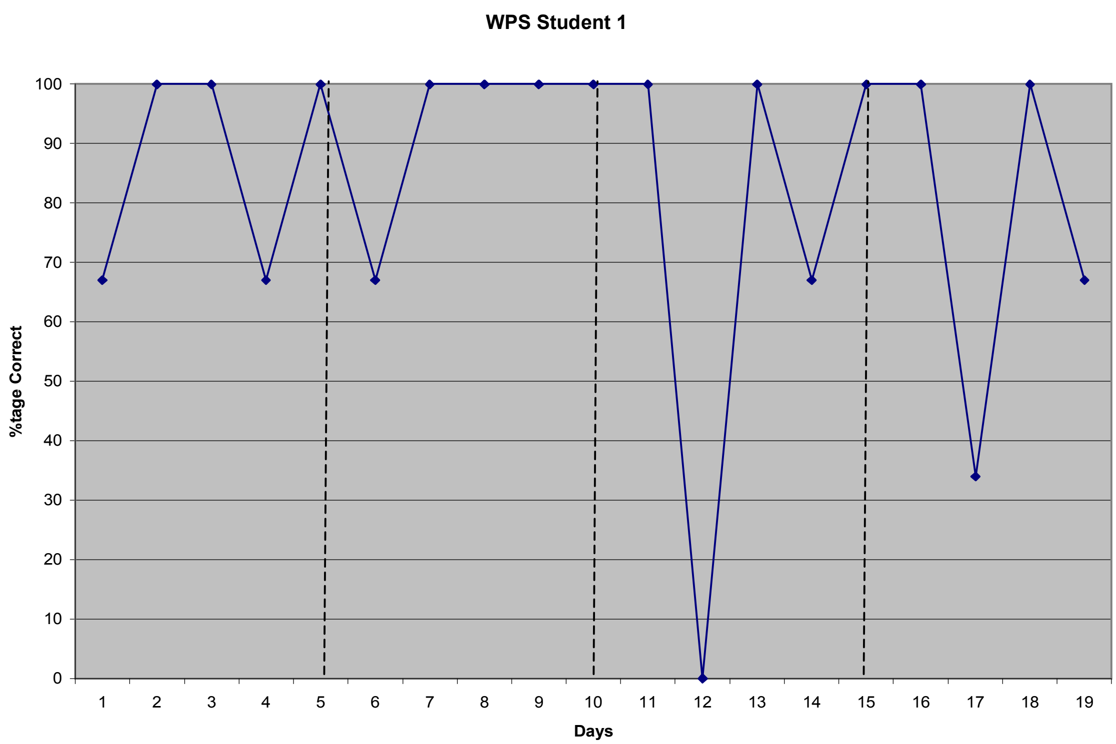
The reliability is the percentage of times in which both observers agreed upon an answer and is noted in decimal form. It was assessed weekly, controlling for observer drift. Recommended levels for inter-rater reliability range from .70 to .90 (Barlow & Hersen, 1984).

Day 1 (all students in Baseline): 1.0
Day 6 (Group 1 in Intervention, Group 2 in Baseline): .94
Day 11 (Group 1 in Generalization, Group 2 in Intervention) 1.0
Note: This was the first day in which students (specifically the students in Group 1) performed at higher levels where significant scoring differences for math communication might become evident. Indeed, on the first assessment of Group 1 in Generalization, there were scoring variances for three of the four students. This caused both examiners to more closely examine one particular aspect of the scoring rubric, question three, which requires students to refer to results when describing how they arrived at their answers. Based on this discussion, the dictated answers of the students in Group 1 were re-scored and inter-rater reliability re-assessed. Inter-reliability after that point was 1.0.
Day 16 (Group 1 in Extended Generalization/Maintenance, Group 2 in Generalization): .94
Day 21 (Group 1 concluded participation in the Study on Day 19; Group 2 in Extended Generalization/Maintenance): 1.0

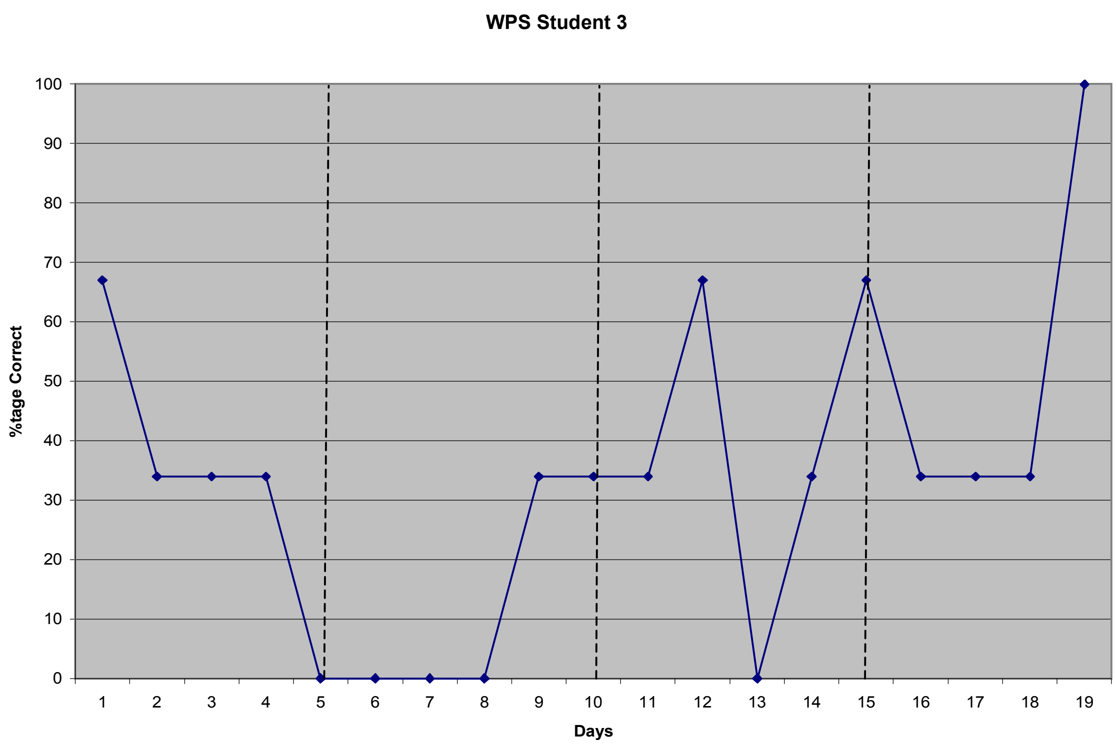
Graph 1A


Word Problem Solving (Group 1)
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Days
Student 1
Student 3
Student 4
Student 8
A =Absent

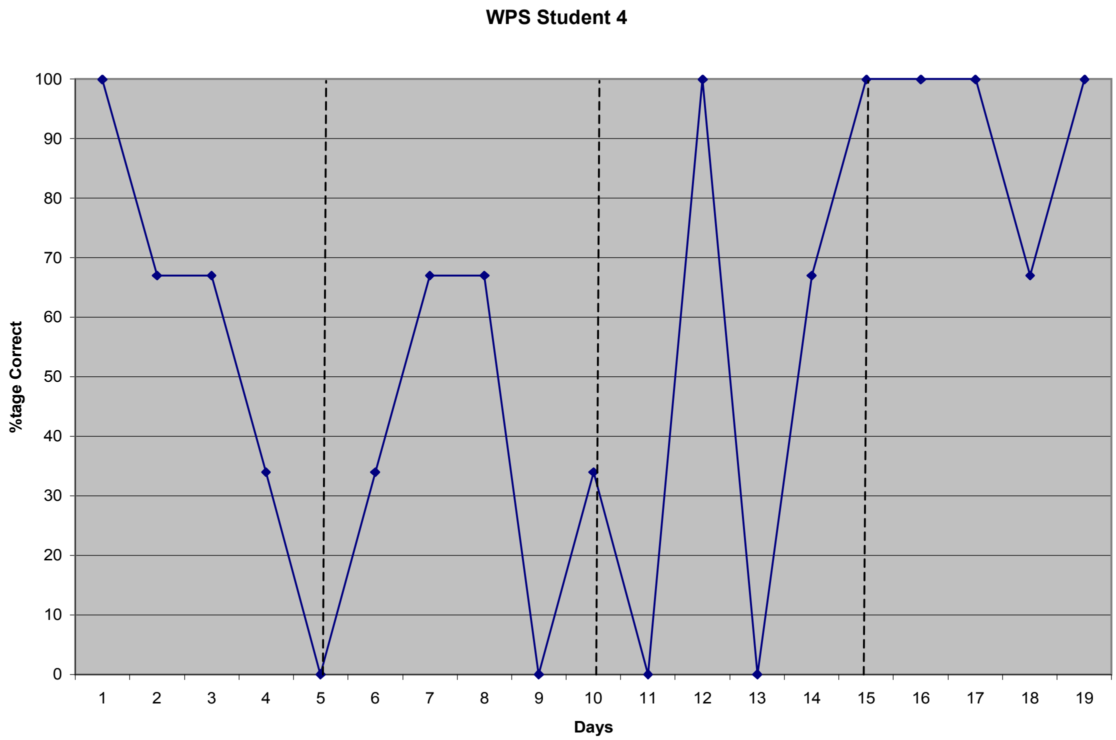
Graph 1A-1


WPS Student 1
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

Graph1A-3

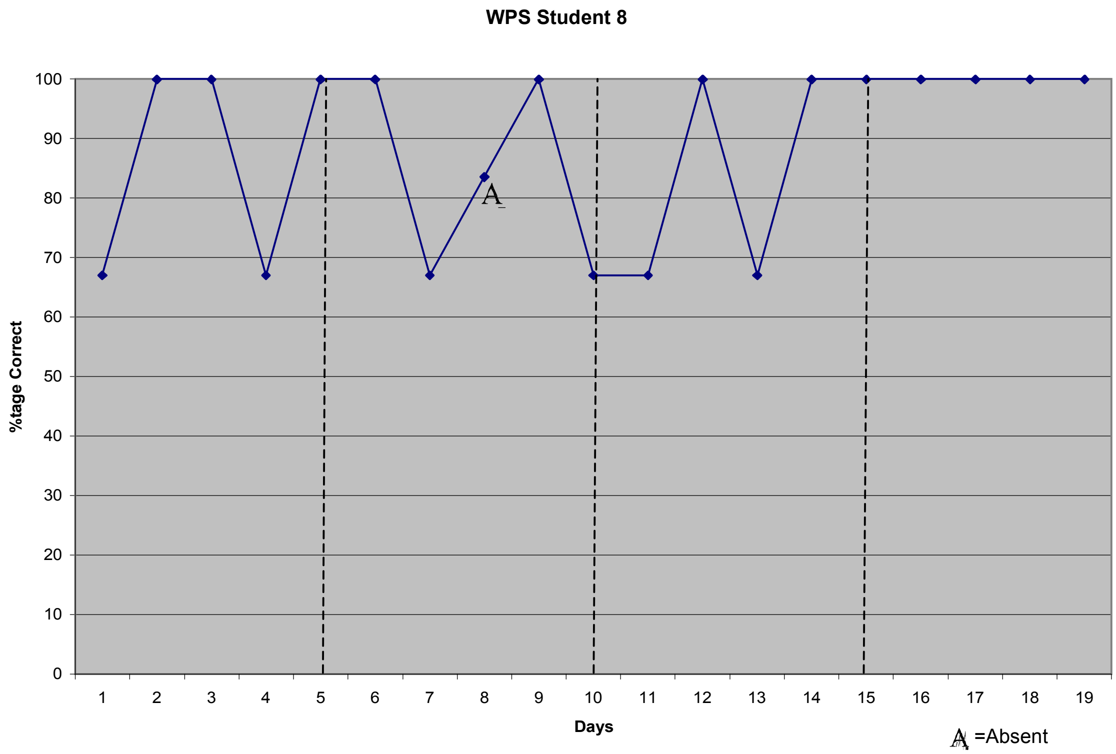

WPS Student 3
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

Graph 1A-4



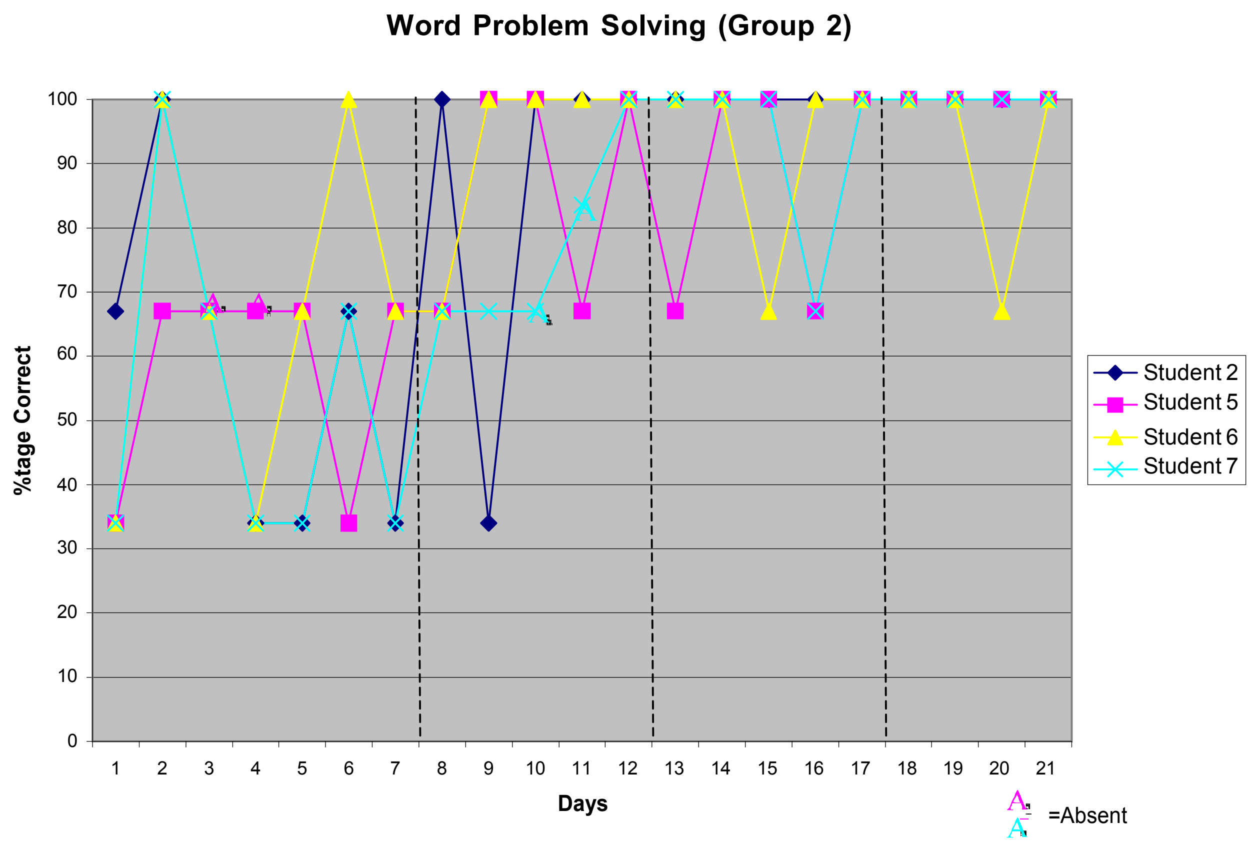
WPS Student 4
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

Graph1A-8



WPS Student 8
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days
A
A =Absent

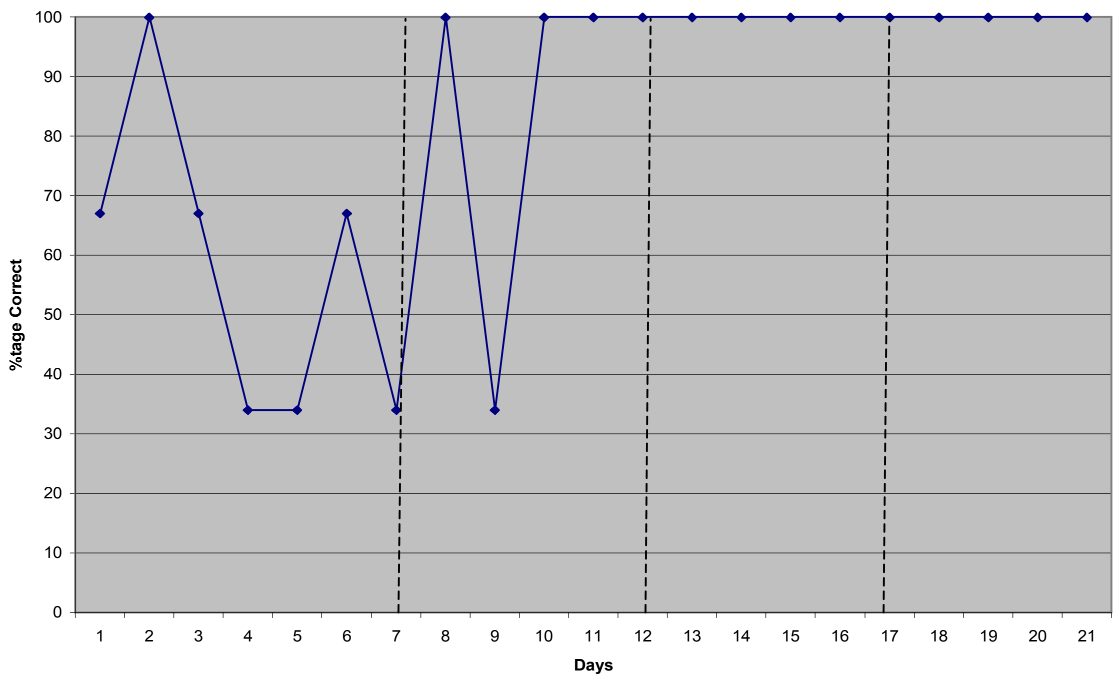
Graph 2A



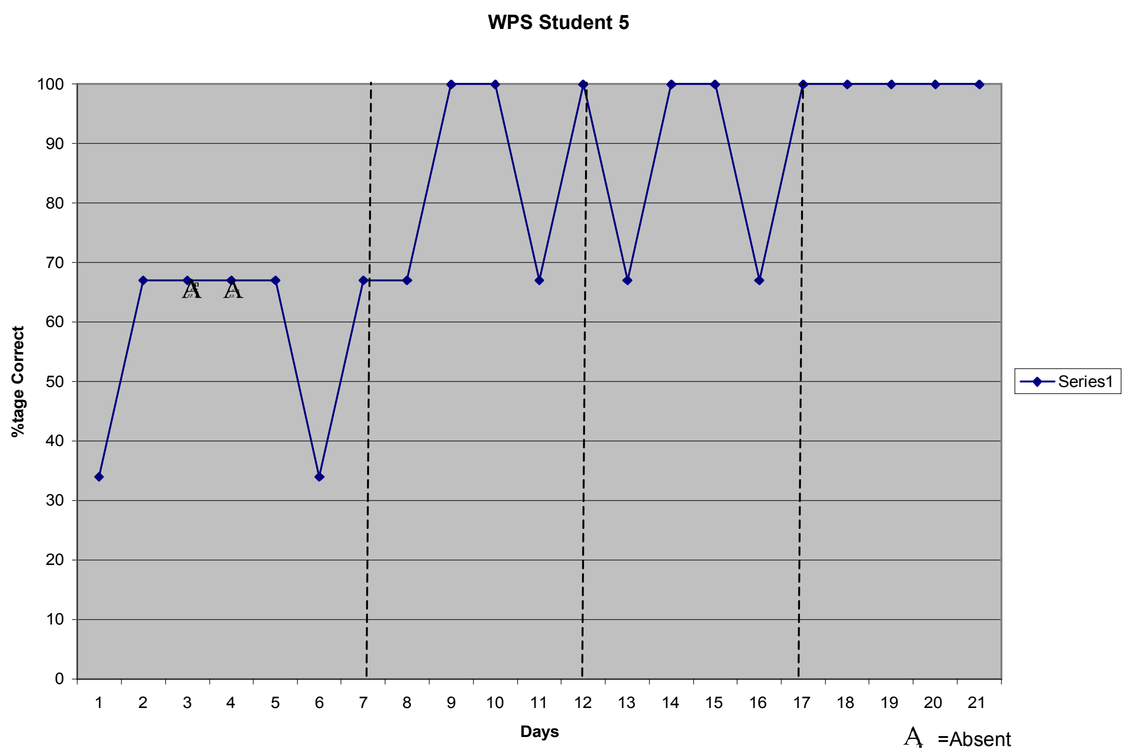
Word Problem Solving (Group 2)
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days
Student 2
Student 5
Student 6
Student 7
=Absent

Graph2A-2

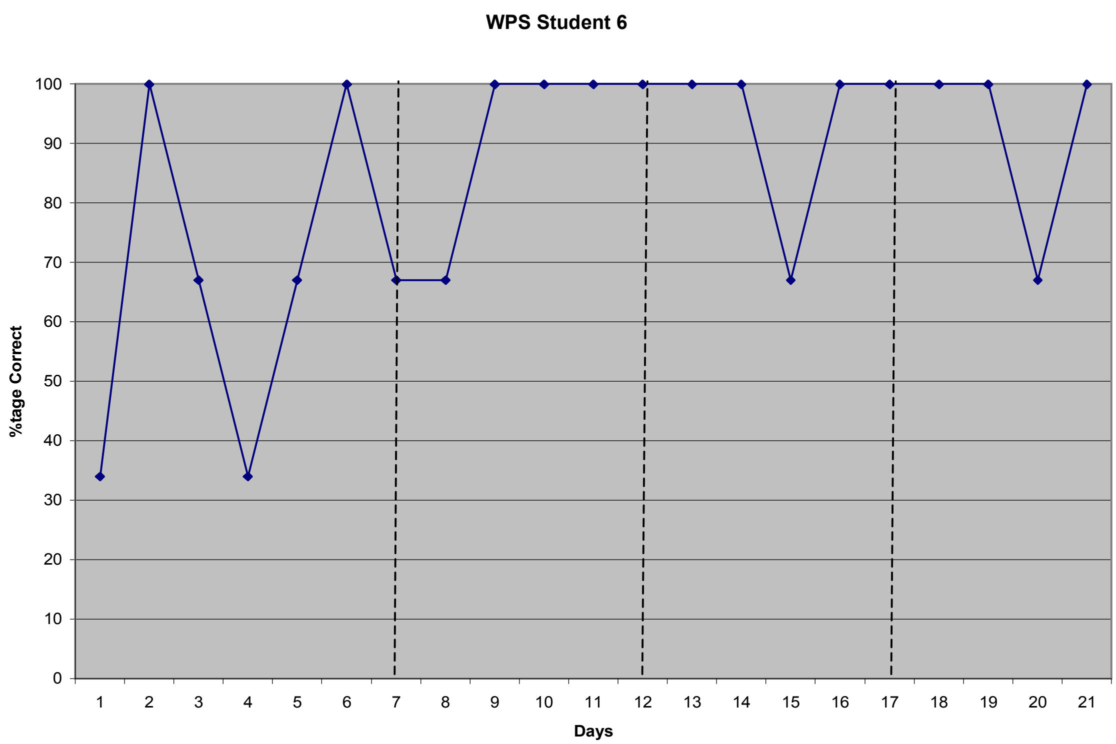
WPS Student 2



Graph 2A-5

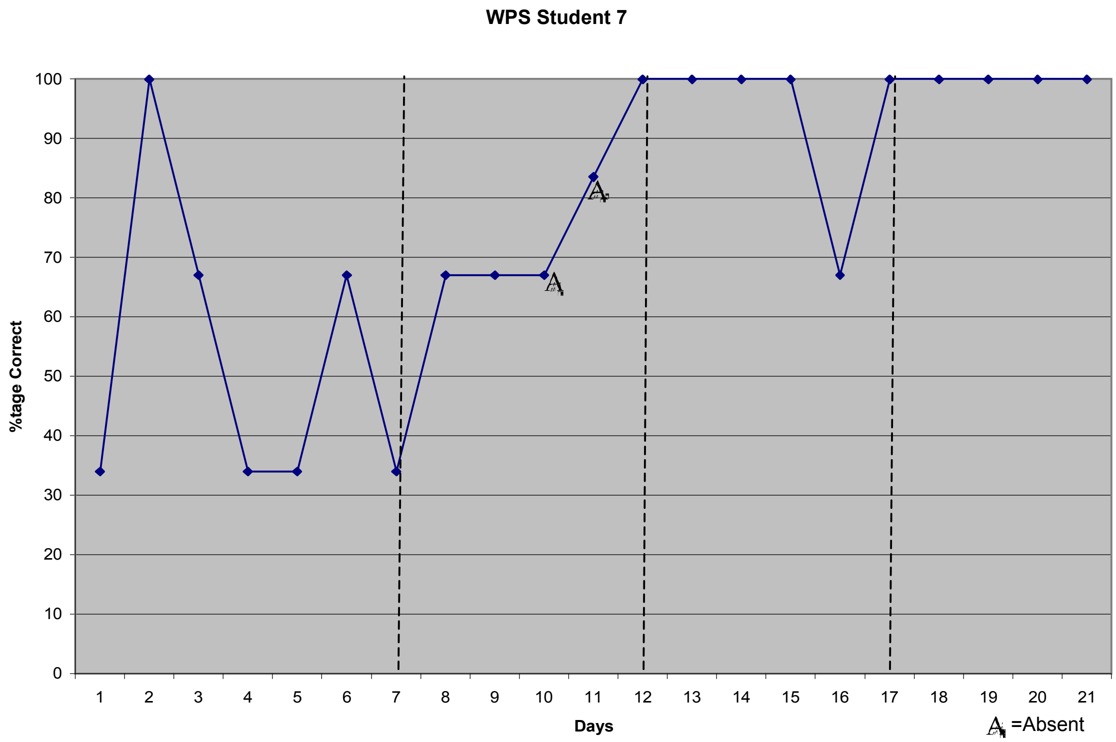

WPS Student 5
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days
A
A
Series1
A =Absent

Graph 2A-6

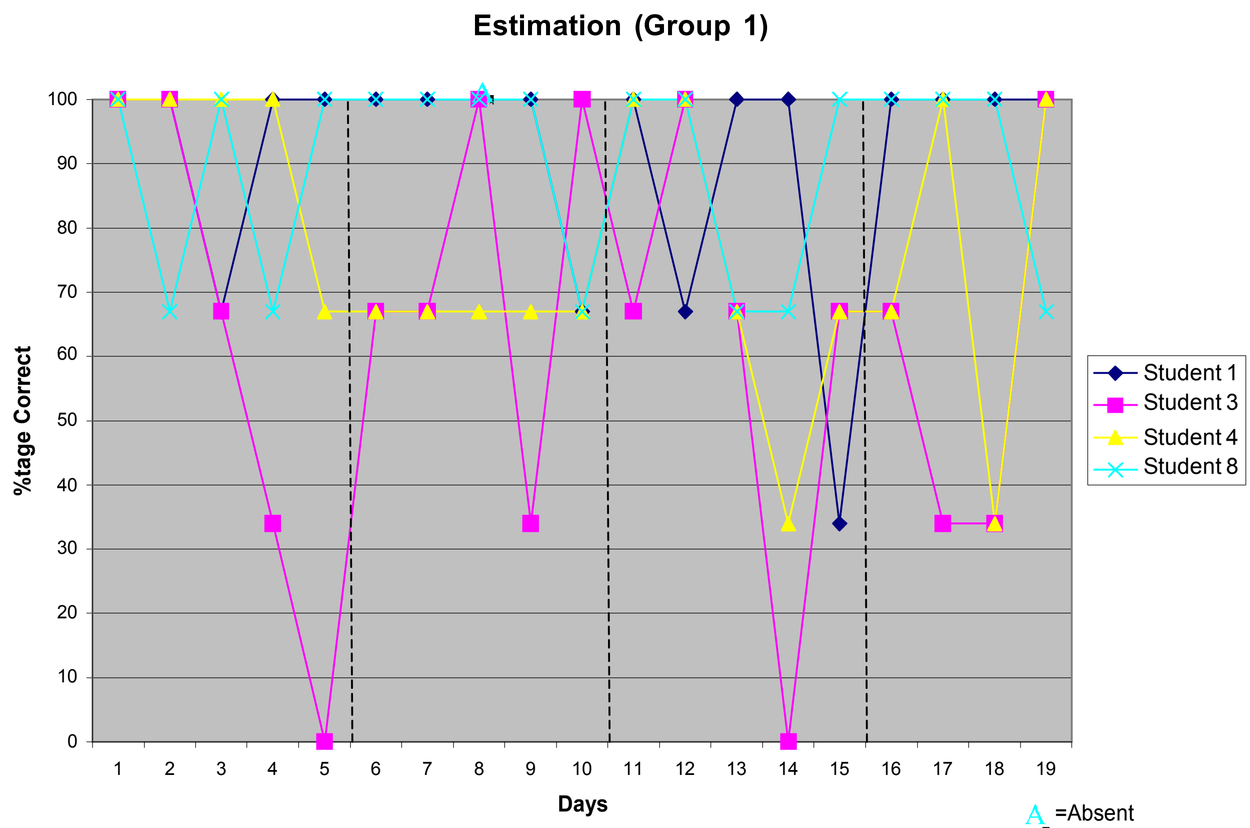


WPS Student 6
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days

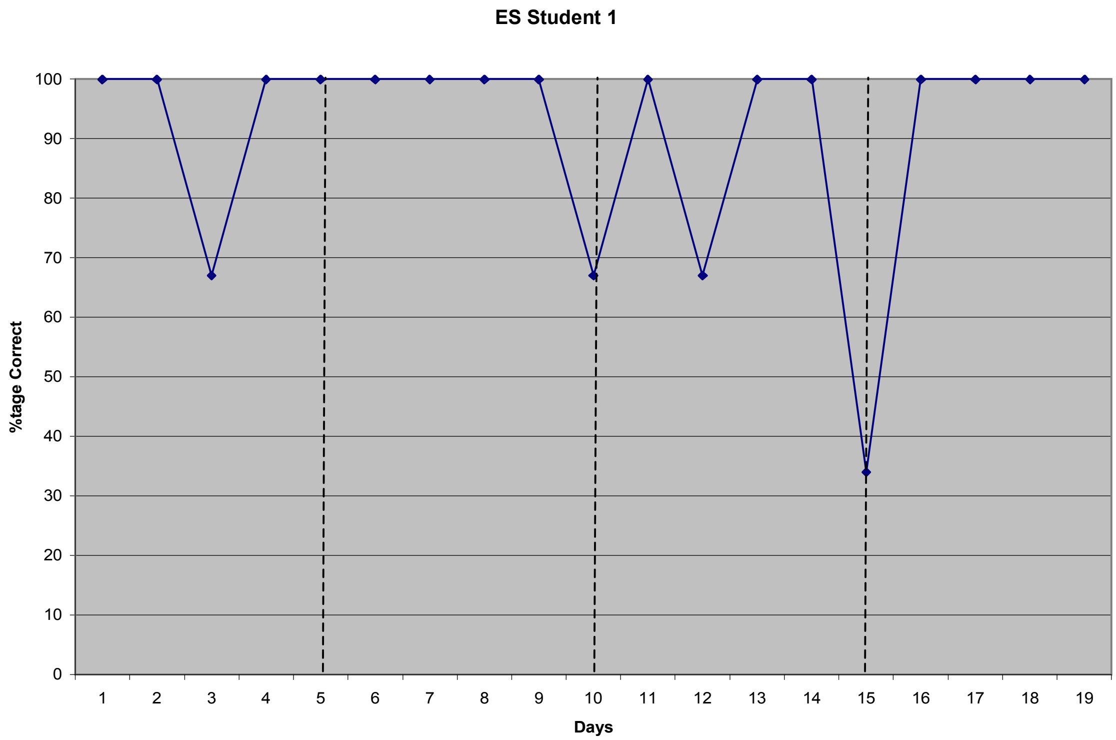
Graph 2A-7


WPS Student 7
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days
A
A
A =Absent

Graph 1B

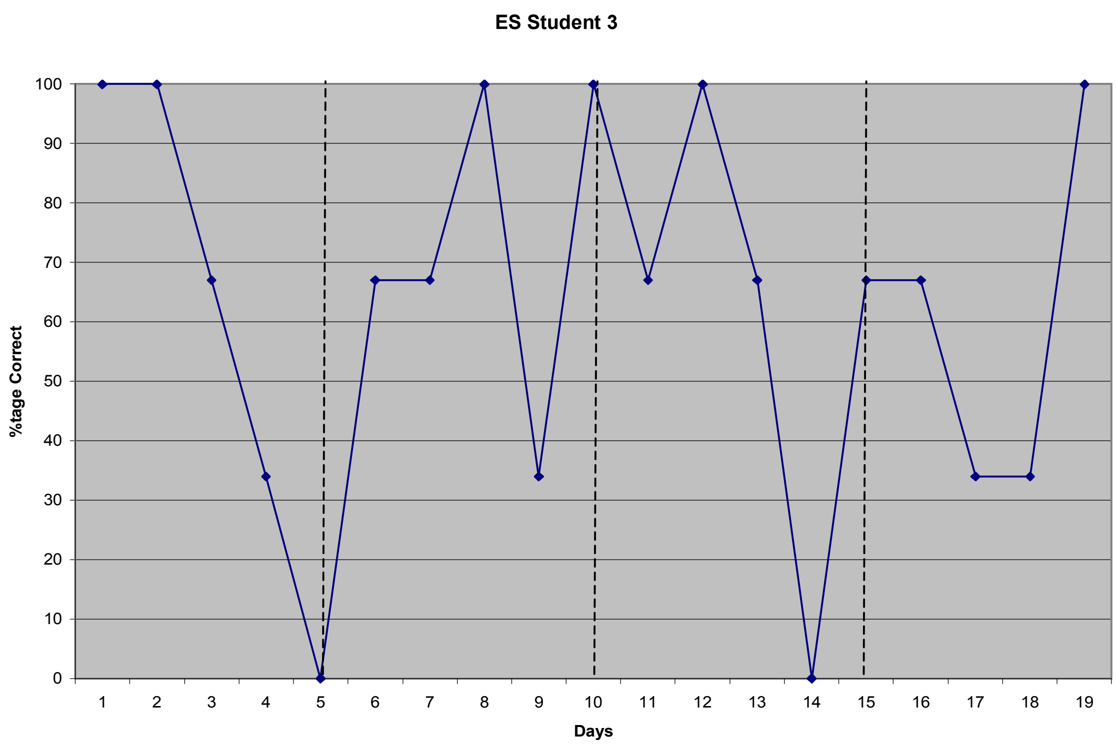

Estimation (Group 1)
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days
Student 1
Student 3
Student 4
Student 8
A =Absent

Graph 1B-1

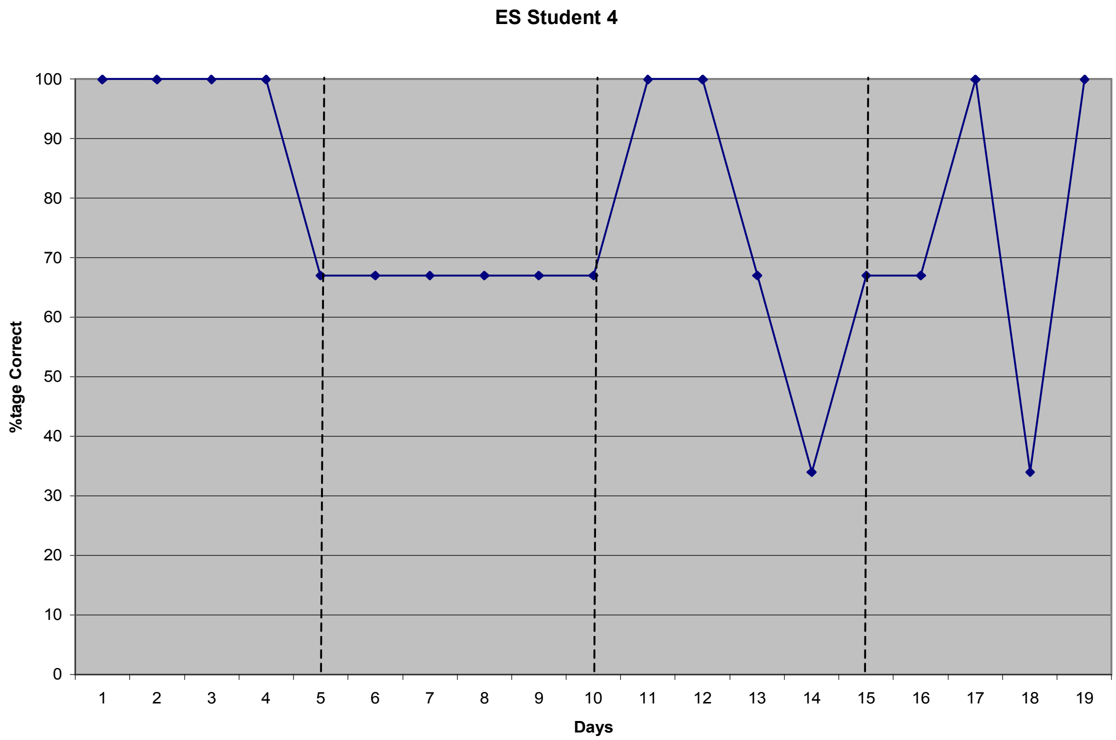


ES Student 1
%tage Correct
0
10
20
30
40
50
60
70
80
90
100
Days
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

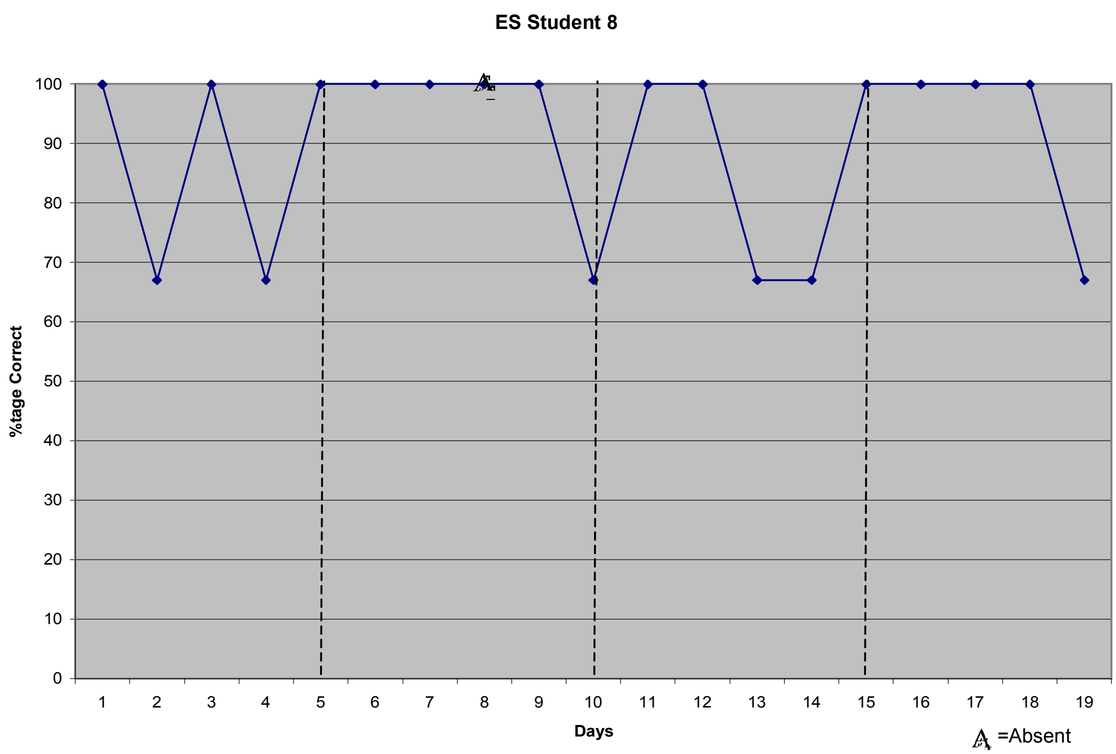
Graph 1B-3


ES Student 3
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

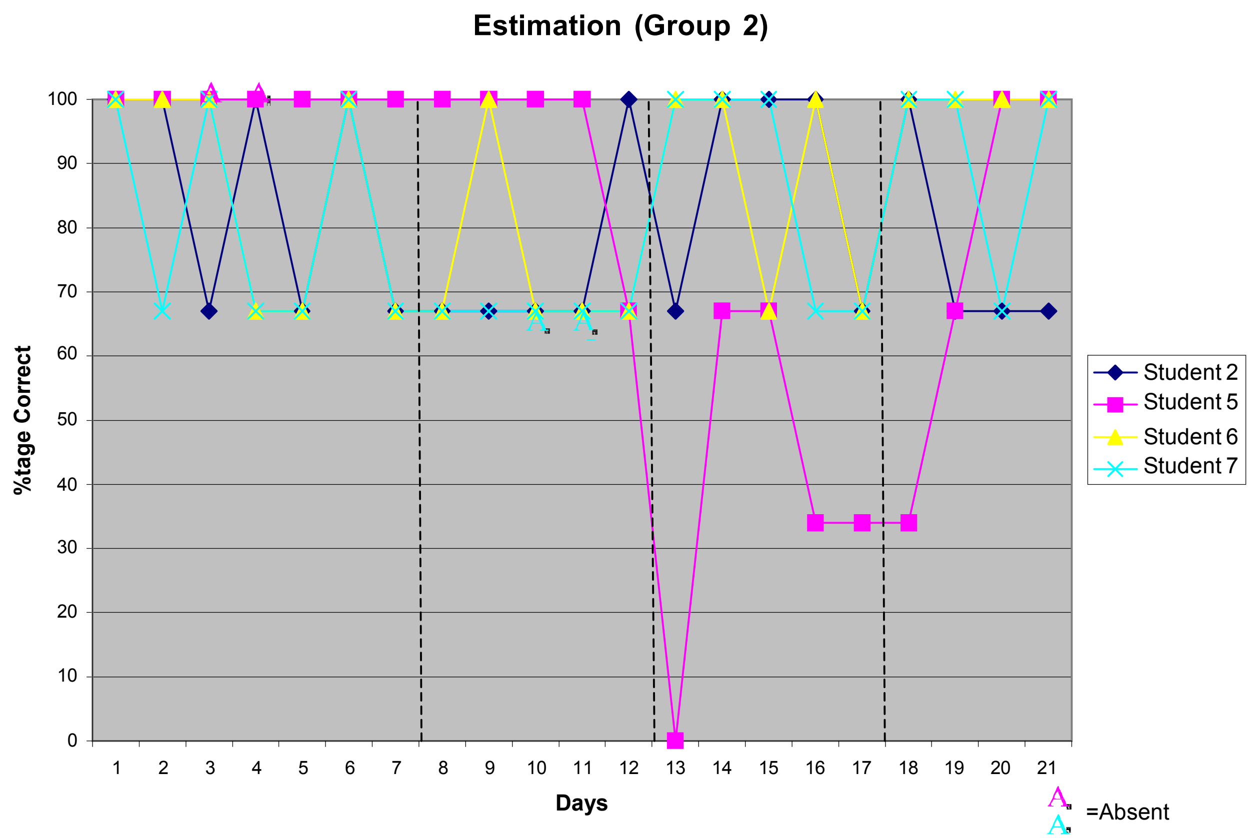
Graph 1B-4


ES Student 4
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

Graph1B-8

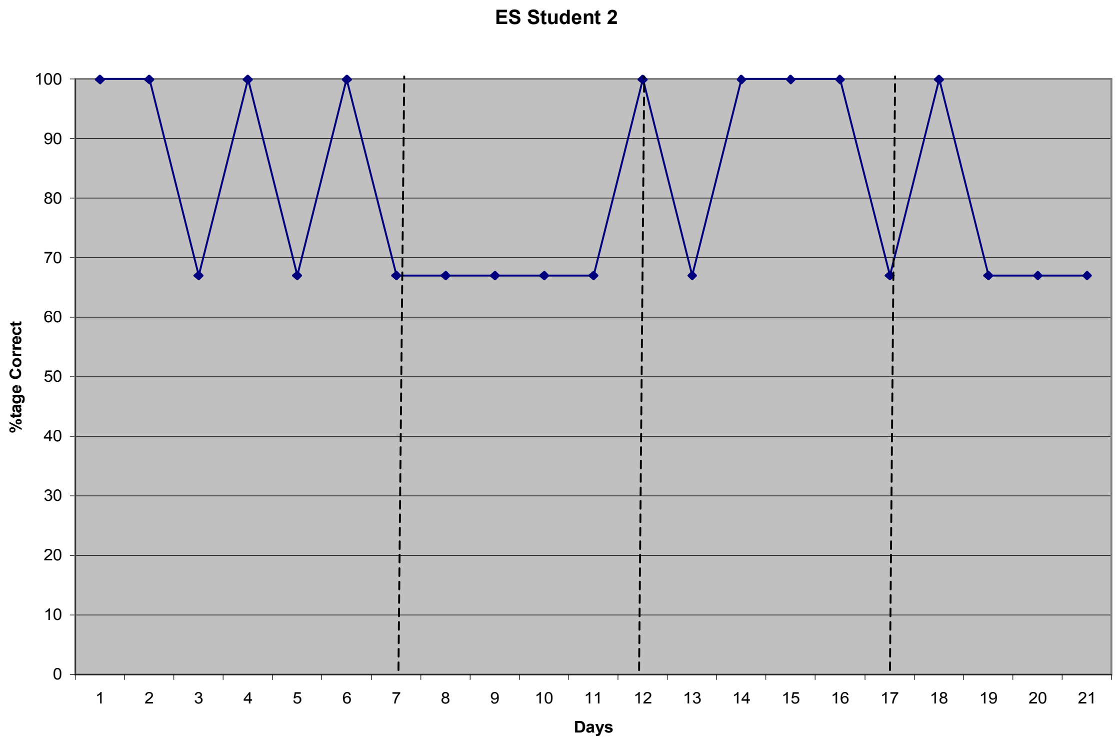

ES Student 8
100
90
80
70
60
50
40
30
20
10
0
%tage Correct
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Days
=Absent

Graph 2B



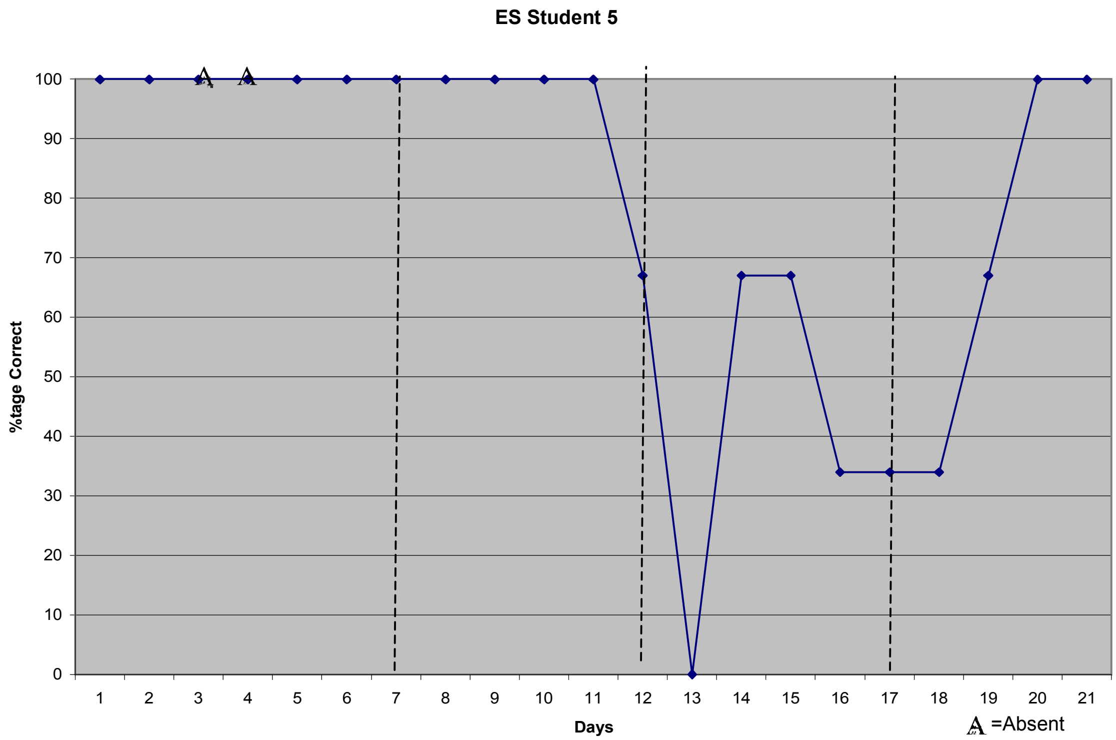
Estimation (Group 2)
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days
Student 2
Student 5
Student 6
Student 7
A
A
=Absent

Graph2A-2



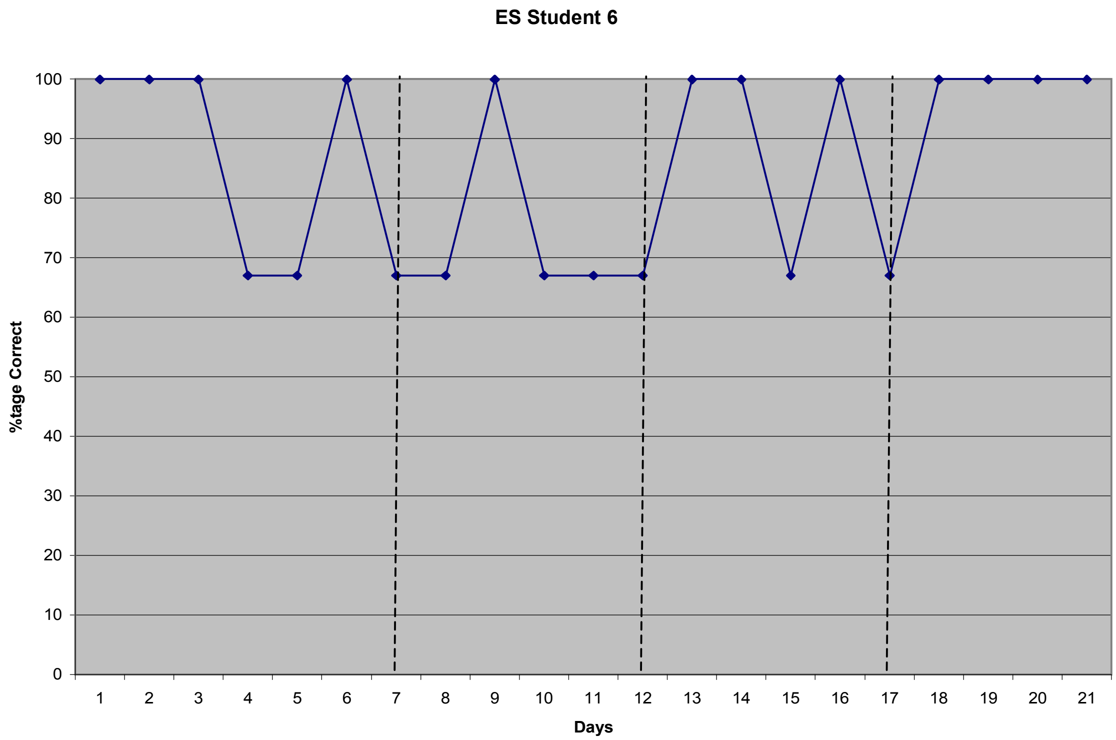
ES Student 2
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days

Graph2A-5

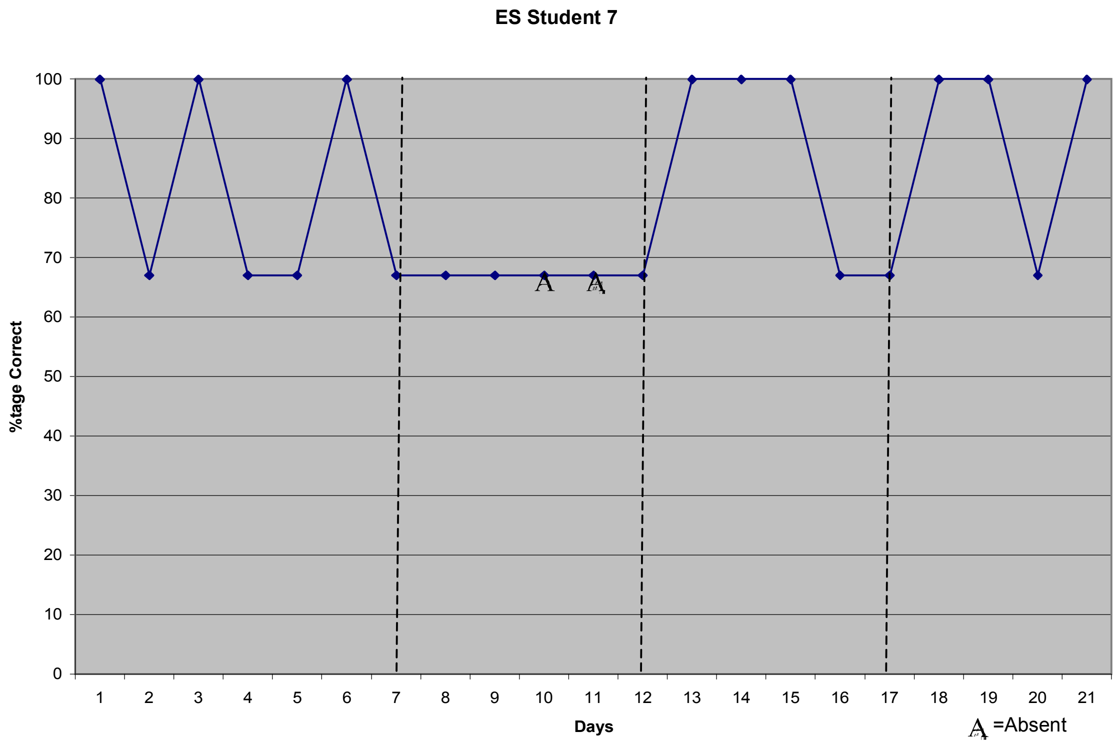


ES Student 5
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days
A =Absent

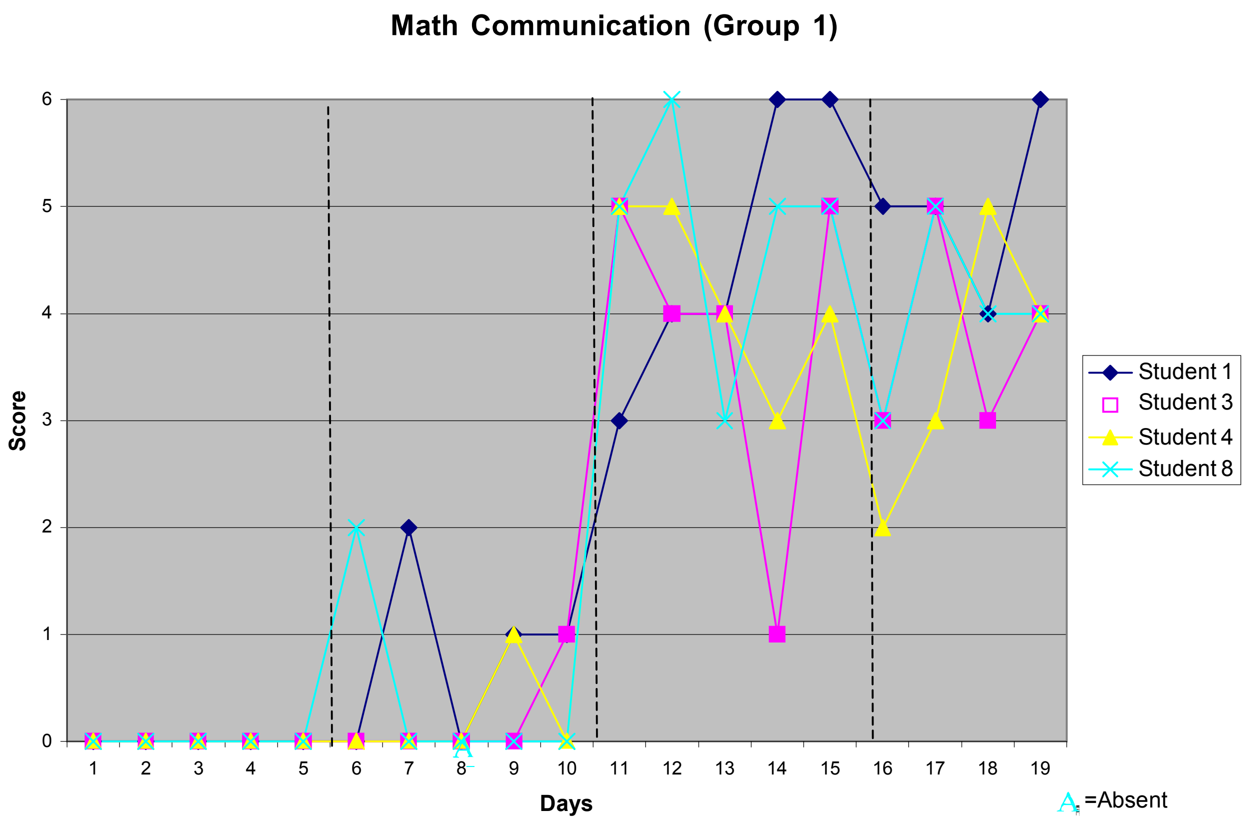
Graph2A-6


ES Student 6
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days

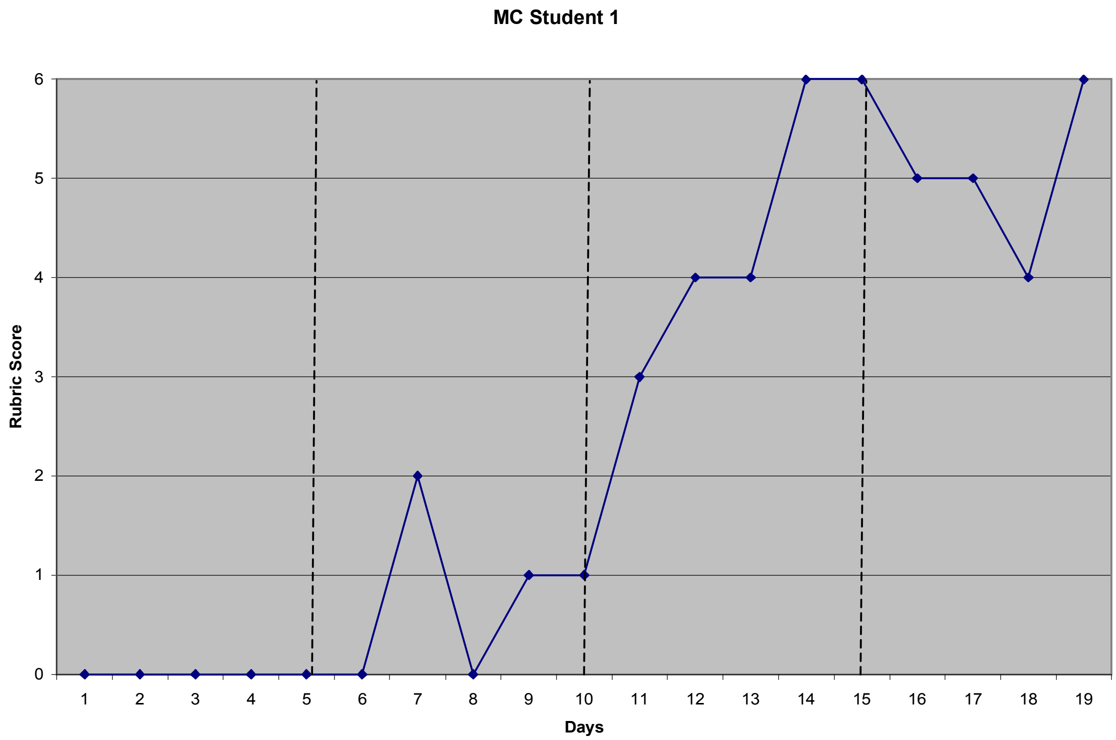
Graph 2A-7


ES Student 7
%tage Correct
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days
A A
A =Absent

Graph 1C

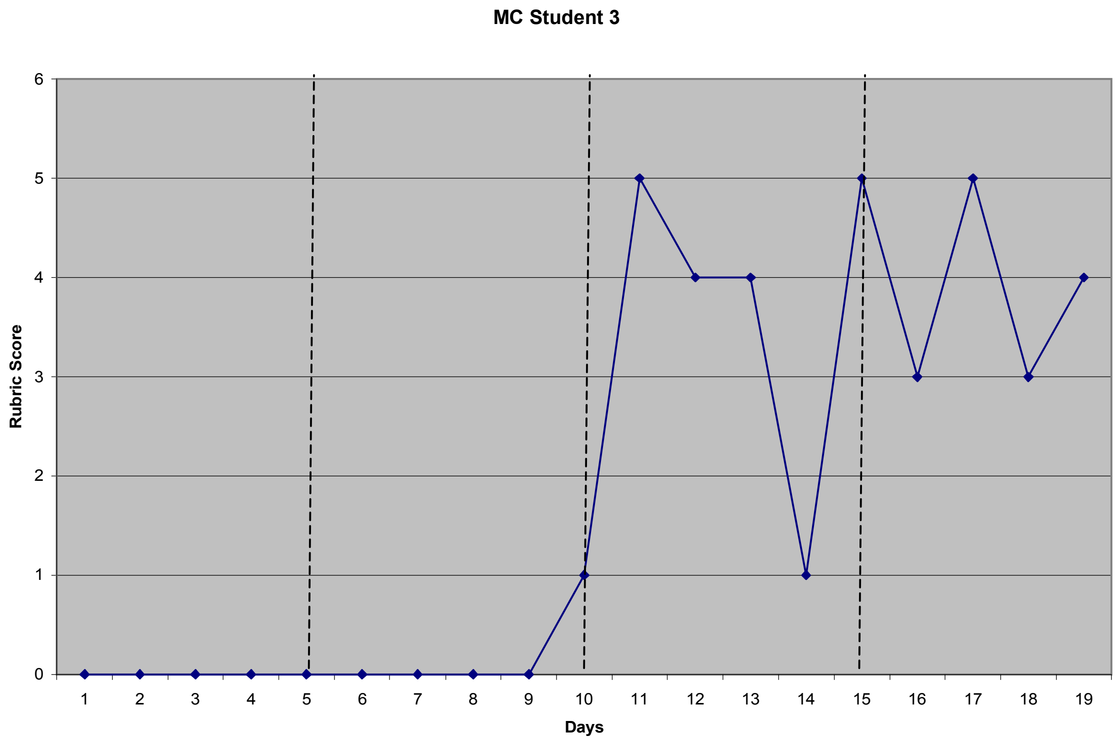

Math Communication (Group 1)
Score
Days
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Student 1
Student 3
Student 4
Student 8
A =Absent

Graph 1C-1

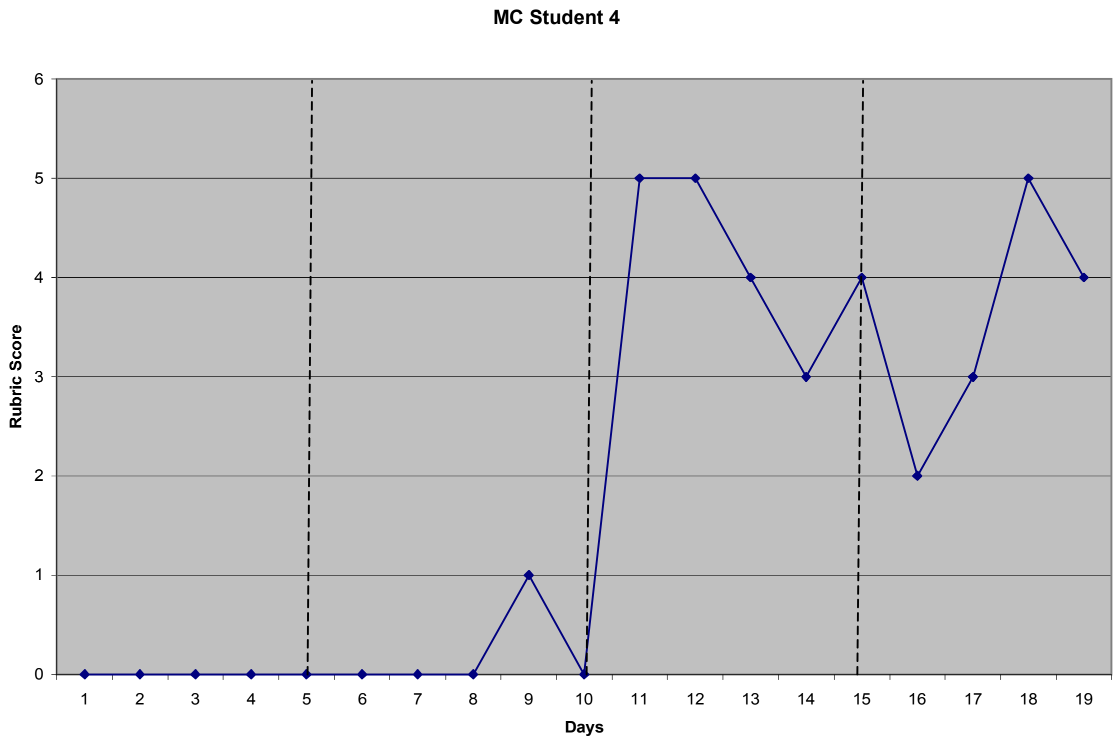


MC Student 1
Rubric Score
Days
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

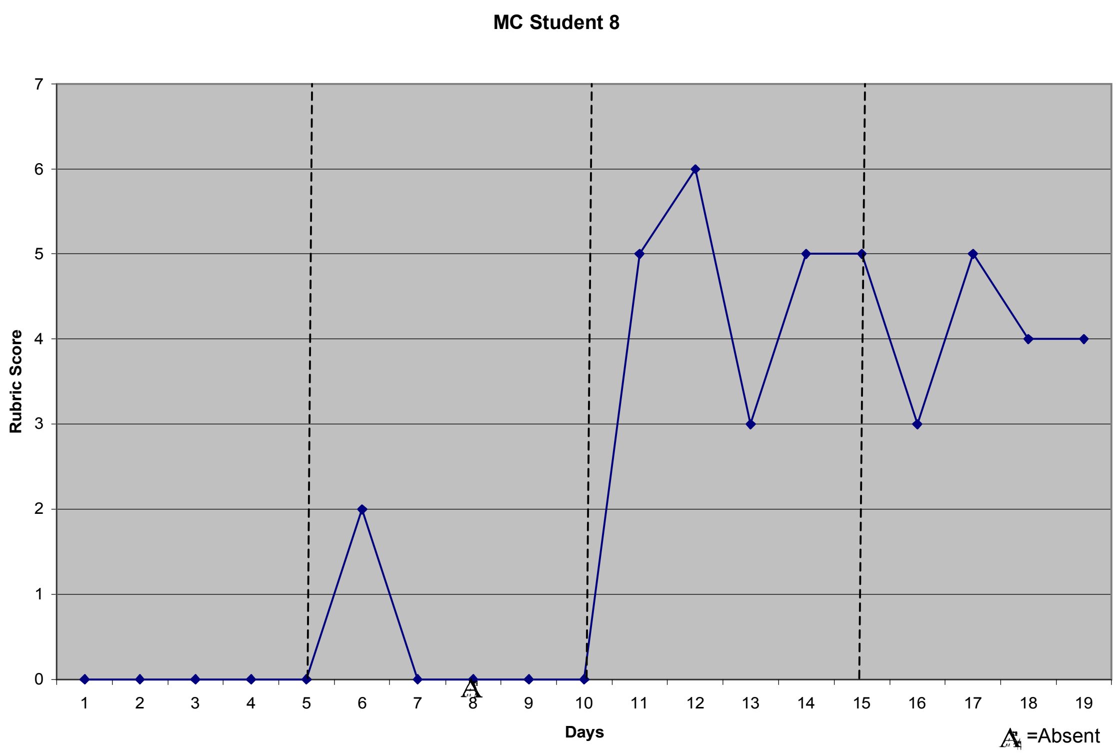
Graph 1C-3


MC Student 3
Rubric Score
0
1
2
3
4
5
6
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days

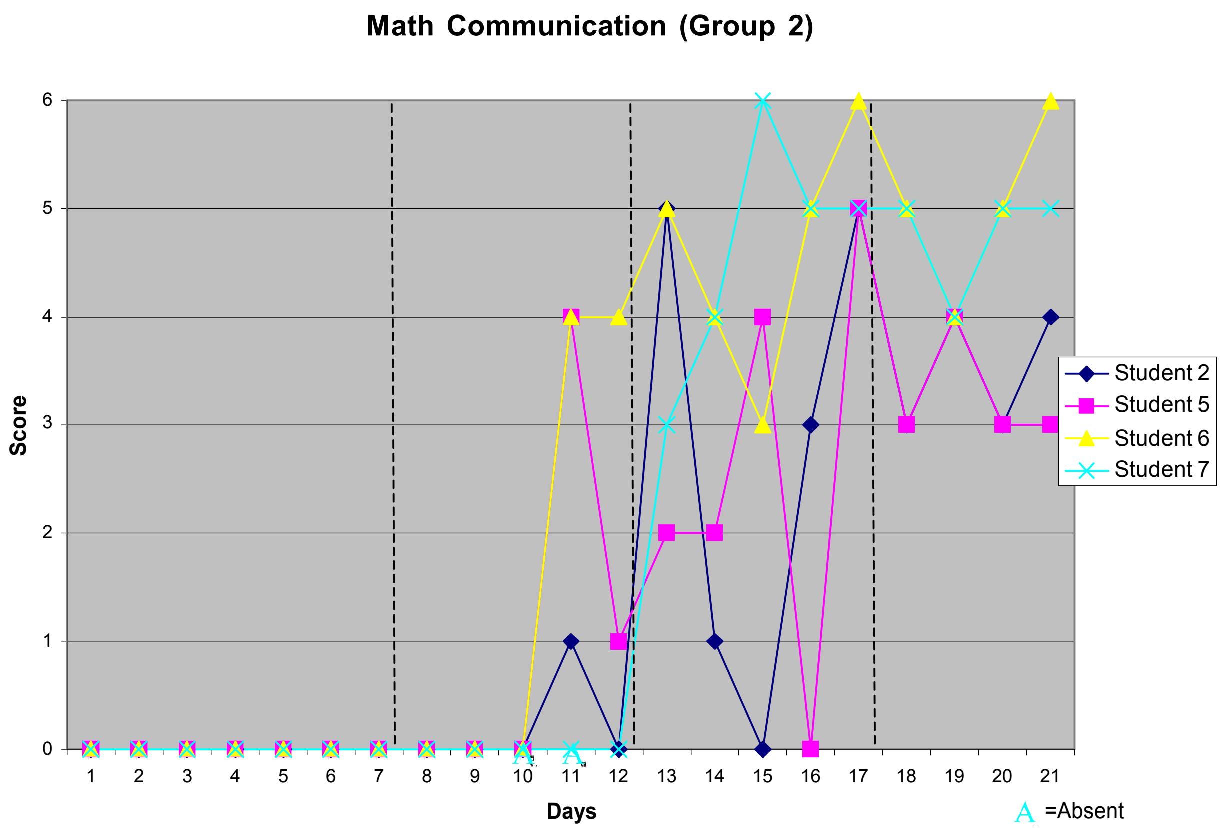
Graph 1C-4


MC Student 4
Rubric Score
Days
0
1
2
3
4
5
6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

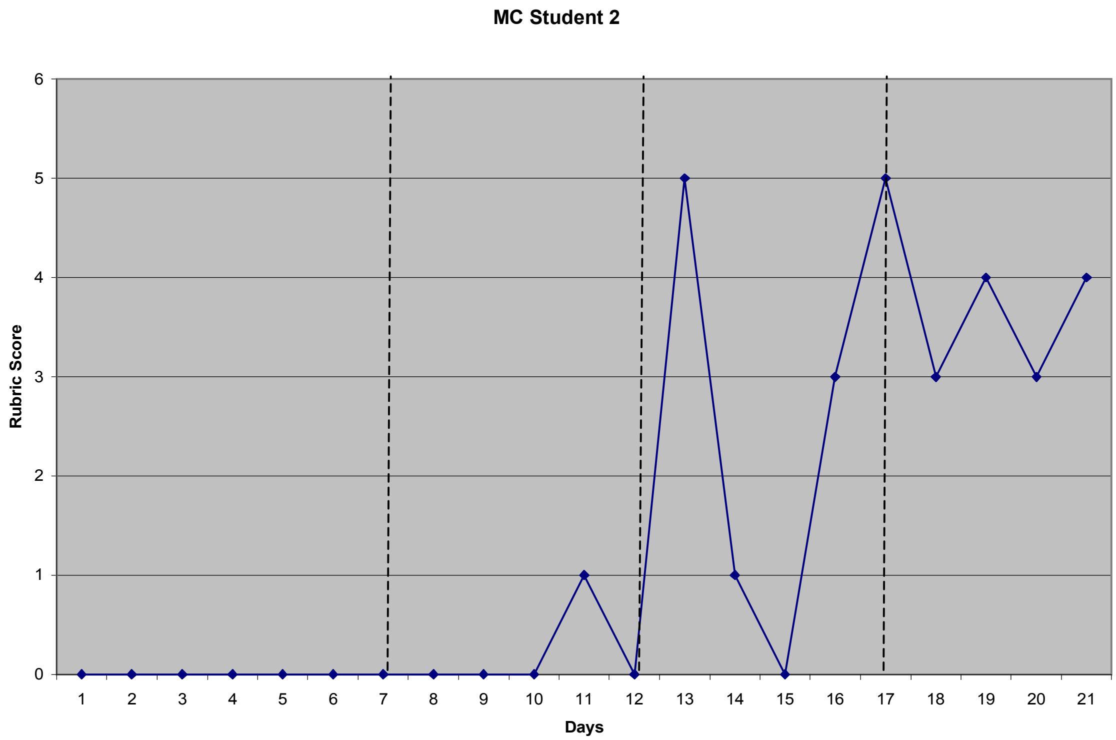
Graph 1C-8


MC Student 8
Rubric Score
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Days
A
A =Absent

Graph 2C


Math Communication (Group 2)
Score
0
1
2
3
4
5
6
Days
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Student 2
Student 5
Student 6
Student 7
A =Absent

Graph 2C-2



MC Student 2
Rubric Score
Days
0
1
2
3
4
5
6
1
2
3
4
5
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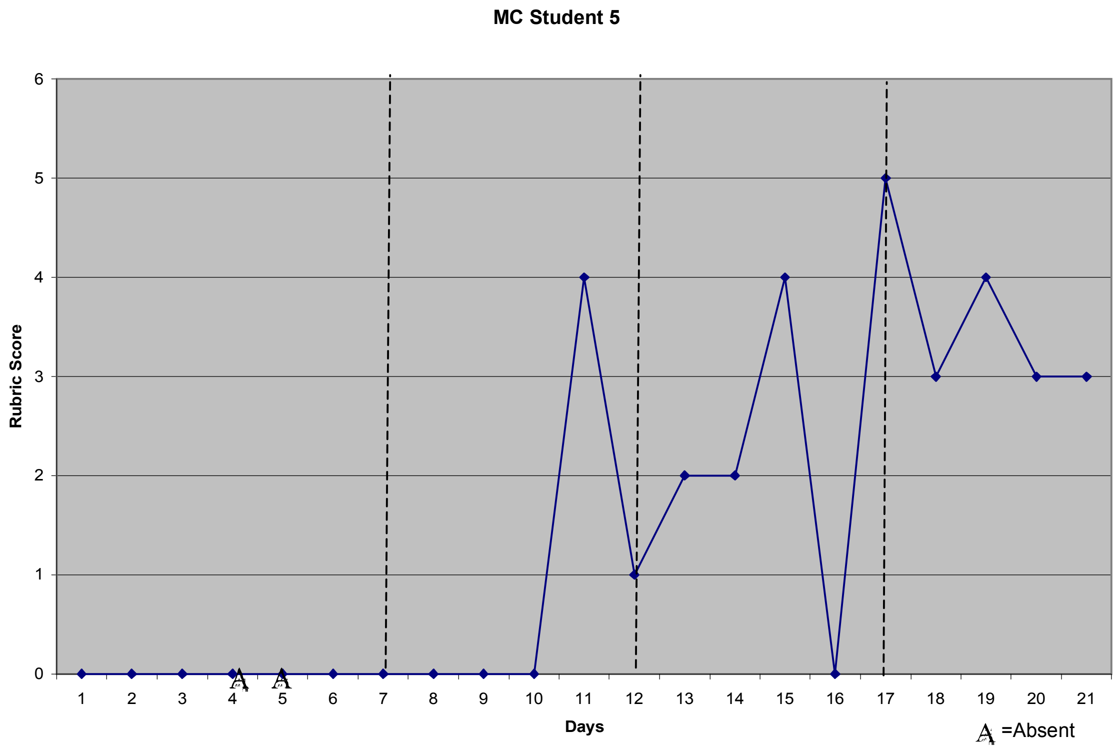
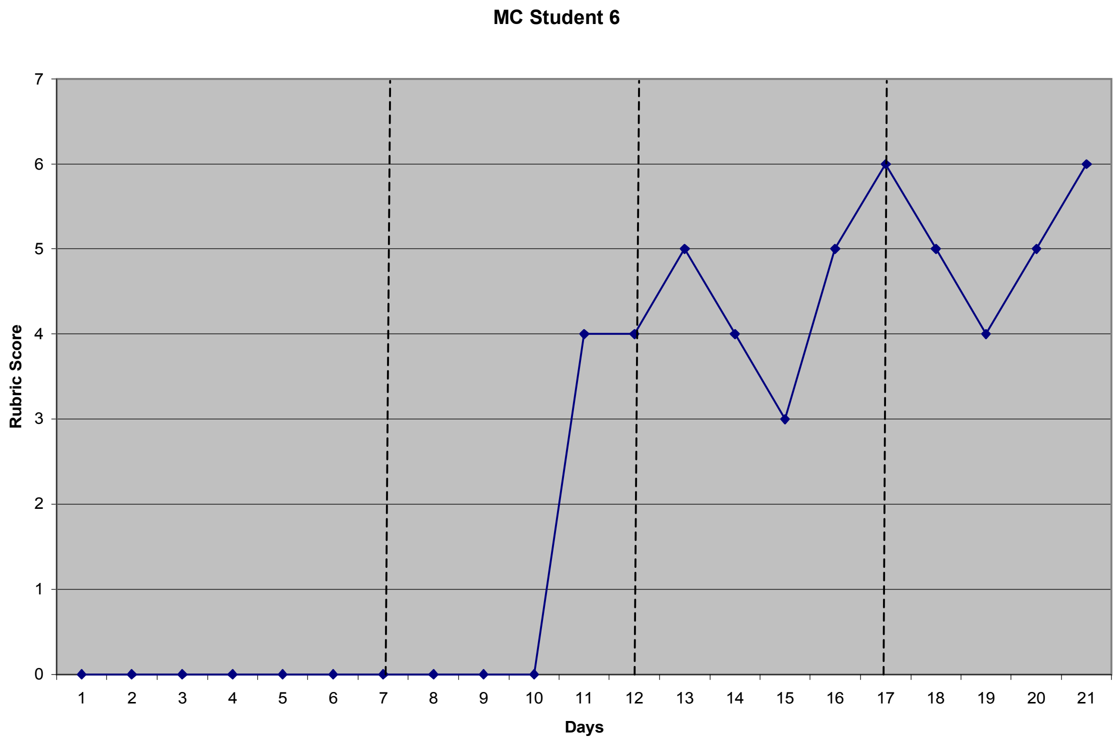
19
20
21

Graph 2C-5

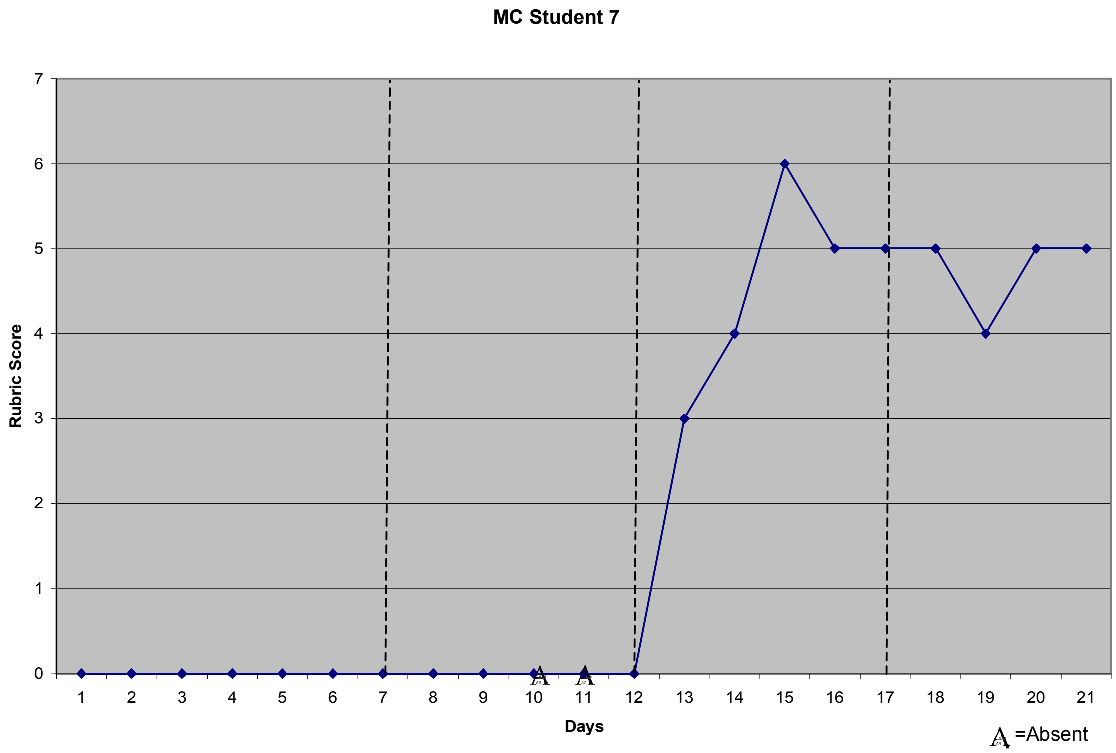


MC Student 5
Rubric Score
0
1
2
3
4
5
6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days
A
A
A =Absent

Graph 2C-6


MC Student 6
Rubric Score
0
1
2
3
4
5
6
7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Days

Graph 2C-7



MC Student 7
Rubric Score
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Days
A =Absent

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CLD Research Committee: Rosenberg, M. S., Bott, D., Majsterek, D., Chiang, B., Gartland, D., Wesson, C., Graham, S., Smith-Myles, B., Miller, M., Swanson, H. L., Bender, W., Rivera, D., & Wilson, R. (1994). Minimum standards for the description of participants in learning disabilities research. Remedial and Special Education, 15(1), 56-59.

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